PERIPHERIESTÜCK CRITICAL ENVIRONMENTS II
READINGS
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IAN L. McHARG: *DESIGN WITH NATURE*

Chapters:

- The Cast and the Capsule
- Nature in the Metropolis
- Processes as Values

Ian McHarg, *Design with Nature*
John Wiley & Sons, Inc., New York, 1992

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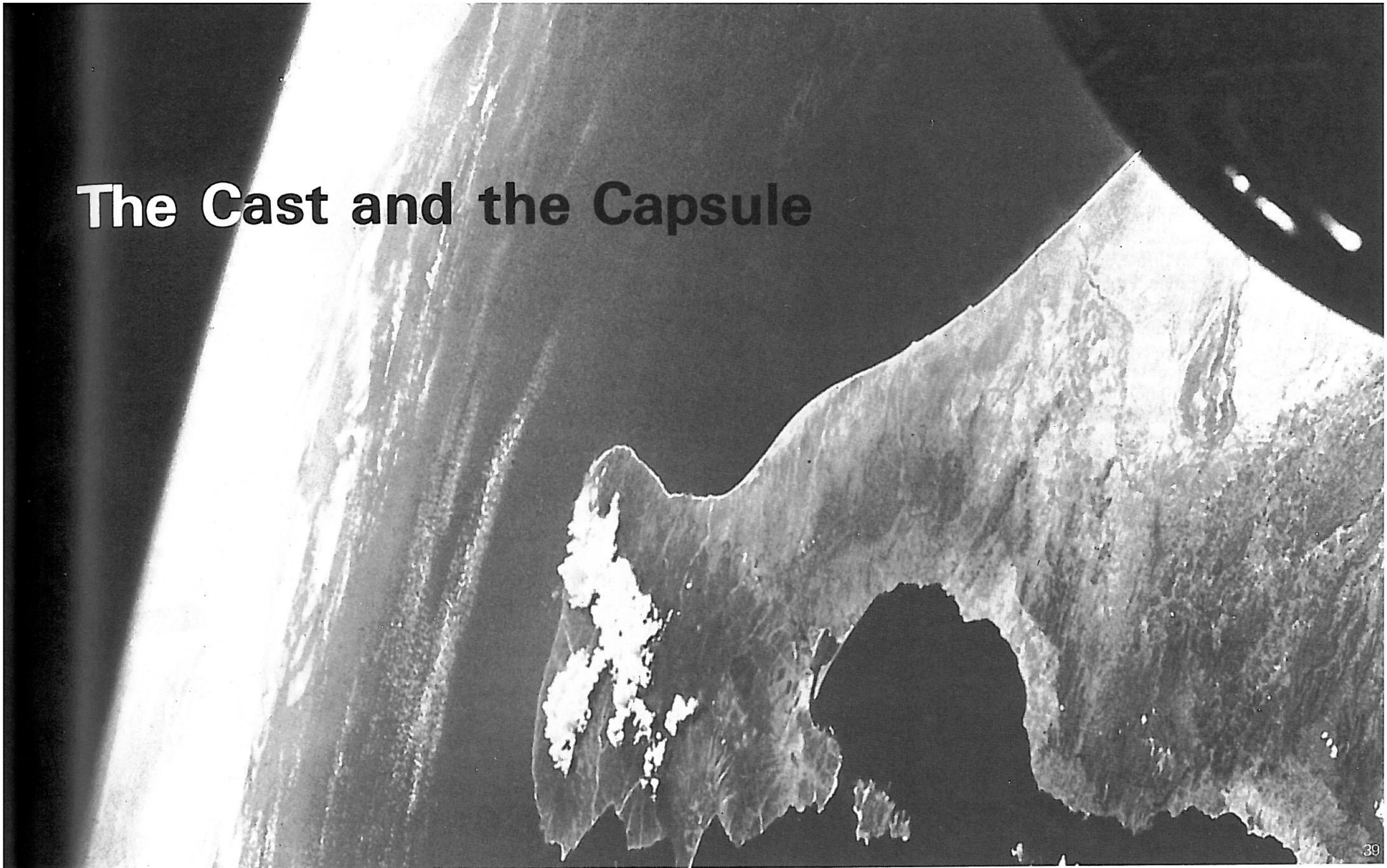
The Cast and the Capsule



Each year I confront a new generation of graduate students, secure in their excellence, incipient or confirmed professionals in one or another of the planning or design fields. My most important objectives in this first encounter are to challenge professional myopia, exclusively man-centered views, to initiate consideration of basic values and to focus particularly on the place of nature in man's world—the place of man in nature.

Over the years I have used two stories mercilessly in order to review accepted values.

The first is paraphrased from an image conceived by Loren Eiseley:*

Man in space is enabled to look upon the distant earth, a celestial orb, a revolving sphere. He sees it to be green, from the verdure on the land, algae greening the oceans, a green celestial fruit. Looking closely at the earth, he perceives blotches, black, brown, gray and from these extend dynamic tentacles upon the green epidermis. These blemishes he recognizes as the cities and works of man and asks, "Is man but a planetary disease?"

The silence that follows provides the appropriate setting for the next story—my own, bred from introspection on the increase of nuclear power.

The atomic cataclysm has occurred. The earth is silent, covered by a gray pall. All life has been extinguished save in one deep leaden slit, where, long inured to radiation, persists a small colony of algae. They perceive that all life save theirs has been extinguished and that the entire task of evolution must begin again—some billions of years of life and death, mutation and adaptation, cooperation and competition, all to recover yesterday. They come to an immediate, spontaneous and unanimous conclusion: "Next time, no brains."

The audience, in common with western society at large, believes that the world, if

*Lecture by Loren Eiseley in the series, *"The House We Live In,"* WCAU-TV, Feb. 5, 1961.

not the universe, consists of a dialogue between men, or between men and an anthropomorphic God: the result of this view is that man, exclusively, is thought divine—given dominion over all life, enjoined among all creatures to subdue the earth. Nature is then an irrelevant backdrop to the human play called Progress, or Profit. If nature is brought to the foreground, it is only to be conquered—man versus nature.

In this context it is salutary to suggest that the path and direction of evolution may not be identical to human ideas of destiny; that man, while the current, latest dominant species, may not be an enduring climax; that brain may or may not be the culmination of biological evolution or it might in contrast be an aberration, a spinal tumor, and finally, although no man will hear it, the algae may laugh last. The burden of proof, then, lies with man and brain. He is required to demonstrate that he is capable of understanding and managing the world of life to ensure survival.

We can conclude that there are two extreme viewpoints of man-nature. In the first, anthropocentric man—ignorant of evolutionary history, innocent of man's dependence, his allies and cohorts, low-browed and brutish—destroys as he goes, while adulating man and his works. (Can we suggest that his aggression is only a cultural inferiority complex?) The opposing view is less certain of man's place. It reserves the right to justify man as not only a unique species, but one with the unequaled gift of consciousness. This man, aware of his past, his unity with all things and all life, proceeds with a deference born of understanding, seeking his creative role.

If we can abandon the sad arrogance of ignorance and introduce a mood of reasonable inquiry, then circumspection will temper our indictment and we can reinterpret the stories. If we assume that man is a beneficent and constructive agent in the world, we could imagine the green celestial fruit as a great epidermis indeed, but we could consider the green film as cytoplasm and the black, brown, gray centers not as blemishes but as nuclei and plastids—directing, producing, storing and circulating material for the cytoplasm: the creative centers in the world life. But if we do offer this kinder interpretation, we must ask whether these centers do indeed perform the roles of nuclei and plastids for the biosphere. I think that in general the answer would have to be that they do not.

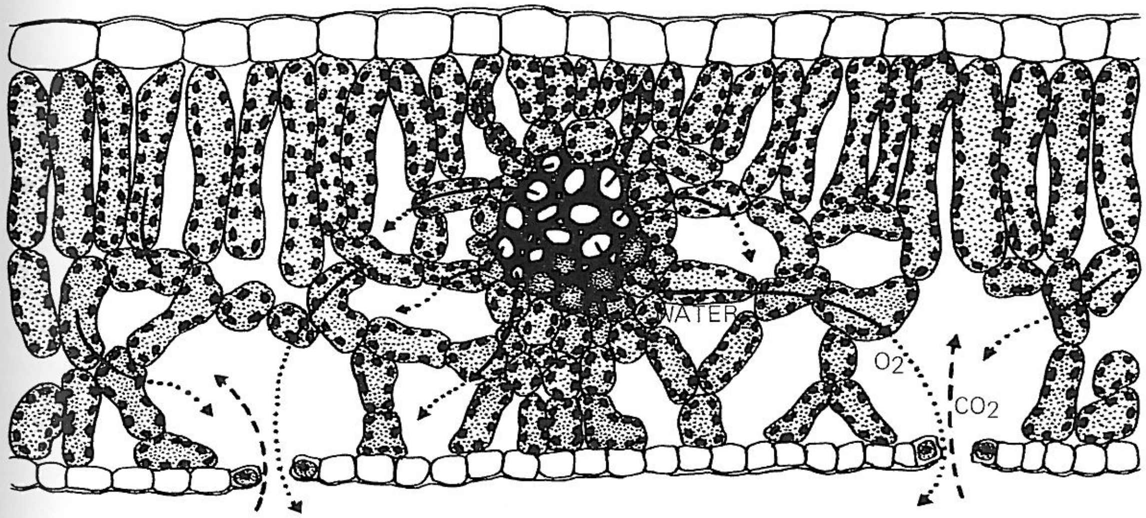
But the mood has at least changed; the cry is no longer the raucous crow of the cock on the dunghill. The question is asked, if man is not the apex of the universe and its total justification, then who are the principal actors? With whom does he share the stage?

Some years ago I spent a most instructive winter with the great architect Louis I. Kahn, searching for the appropriate elysian site for a prospective temple of science, the research arm of a large corporation. I learned much from my travels with this most perceptive of architects, but my knowledge was even more enlarged by an encounter with a member of the research organization. He was designing an experimental environment: his task was to find out how an astronaut might be sent to the moon with the least possible baggage to sustain him. This, of course, required a recirculating, which is to say, a biological system. The experiment design required a plywood capsule with a fluorescent tube representing the sun, a quantity of air, some water, some algae growing in water, some bacteria and a man. This is, you will agree, a modest hoard of groceries for so long a trip. In the hypothetical capsule the man breathes air, consumes oxygen and exhales carbon dioxide; the algae consume carbon dioxide and expel oxygen into the air which the man breathes, and so an oxygen-carbon dioxide cycle is ensured. The man thirsts, drinks some water, urinates, this passes into the water medium in which the algae and bacteria exist, the water is consumed by the algae, transpired, condensed,

ALGAE*

*Drawings by Harold J. Walter, *Algae in Water Supplies* by C. Mervin Palmer, Public Health Service Publication No. 657, U.S. Department of Health, Education and Welfare, Washington, D.C., 1962, Plates 1 & 2.

CHLOROPLAST*



LEAF SECTION**

After Sinott and Wilson, ***Nature: Earth-Plants-Animals,* Doubleday & Company Inc., New York, 1960, p. 72.

*Photo micrograph, NAVICULA PELLICULOSA (Breb.) Hilse; 26,000:1, ***Electron Microscopy of Diatom Cells*** by R.W. Drum, H.S. Penkratz and E.F. Stoermer, J. Cramer, Lehre, 1966, plate 563.

the man drinks the condensations and a closed cycle of water exists. When hungry, the man eats some algae, digests them, then defecates. Subsequently, the decomposers reduce the excrement into forms utilizable by the algae, which grow. The man eats more algae, and so a food chain has been created. The only import to the system is the light from the fluorescent tube—fossil sunlight; the only export from the system is heat.

Alas, experiments of this kind have not been sustained for more than twenty-four hours, a sad commentary on our understanding of man-nature. Nonetheless, they do contain splendid instructional material for the observer. The system depends first upon the sun, the net production of photosynthesis after respiration, upon the water and upon the cycling and recycling of the materials in the system by the decomposers. It is quite clear that the process requires that the substance or wastes, the output of one creature, are the imports or inputs to the others. The oxygen wastes of the plant were input to the man, the carbon dioxide of the man input to the plant; the substance of the plant input to the man, the wastes of the man input to the plant; the wastes of man and plant input to the decomposers, the wastes of these the input to the plant: and the water went round and round and round.

Is this indeed the way the world works? Yes, at least in essential terms. United we are as men, plant parasites, happily consuming the oxygen wastes of plant metabolism, rescued from encompassing ordure by both the decomposer and the plant, eating, burning and thus sustaining life from the energy of the sun, transmuted by photosynthesis. Now before we indulge in fulsome self-praise for our services to both plant and bacteria, let us stop to consider that they both existed before man and need him not at all. Our wastes are useful, but not necessary.

When I first pondered upon this experiment I found that I had to reformulate my view of

man-nature. Instead of a paradise with Adam and Eve placed large in a garden graced by some benign, beautiful and useful plants and animals, the experiment showed that these myriad, beautiful creatures, thought to be a measure of grace added to life, were indeed indispensable, the source of life. Had the astronaut traveled to the moon with his companions, there is some doubt as to whether he would have found the algae and decomposers beautiful, but he would clearly have concluded that they were indispensable.

Moreover, whatever view our moon traveler had of man and environment as separate entities before his departure, it would surely have crossed his consciousness that, given enough time, the probability existed that all that had once been algae might well be man, all that had once been man, algae. The only difference between them, in terms of matter, lay in the templates of the genetic codes. What then is the environment? What then is man?

As I never obtained a college degree and entered graduate school without this dispensation, I never acquired the illusion of being educated which these diplomas often confer. Teaching is that device whereby I assemble a fragmentary, ragged and belated education. As it incurs no cost to the student and cannot be terminated with a degree, it clearly has certain advantages. But it does also have embarrassments, not least of which is the consternation of confronting the commonplace of knowledge as total novelty late in life. I well remember that occasion, when I first heard that all life, with minor exceptions, is now, and forever has been, entirely dependent upon photosynthesis and the plant. I recall looking around me, searching for other eyes equally overwhelmed by this revelatory statement. I found only the dead faces of those who had long since absorbed this information and for whom it had no moving power.

And that was not all. Not only is the chloroplast the overwhelmingly dominant mechanism whereby the light of the sun is transmuted into the substances supporting all life, the sugar and carbohydrates, but there are grounds for believing that it is from the exhalations of all plants in all time that an atmosphere with free oxygen has developed. Indeed, all food, all fossil fuels, fibres, all atmospheric oxygen, the stabilization of the earth's surface and its terrestrial water systems, the melioration of climate and microclimate have been accomplished by the plant: all animals and thus all men were plant parasites. It is the plant that colonized the land and thus permitted the evolution from the sea of amphibians, reptiles, mammals and man, and this dependence persists unchanged. Nor is this basic reliance negated by the fact that many animals perform essential services for plants.

This realization of dependence was a crushing blow to anthropocentrism. I looked around to see what effect this had had upon the class. Were they aware that, at least in thermodynamic terms, the world consisted of a working partnership between the sun and the leaf as man looked on—irrelevant, smiling benignly upon the scene, secure in the illusion of his primacy?

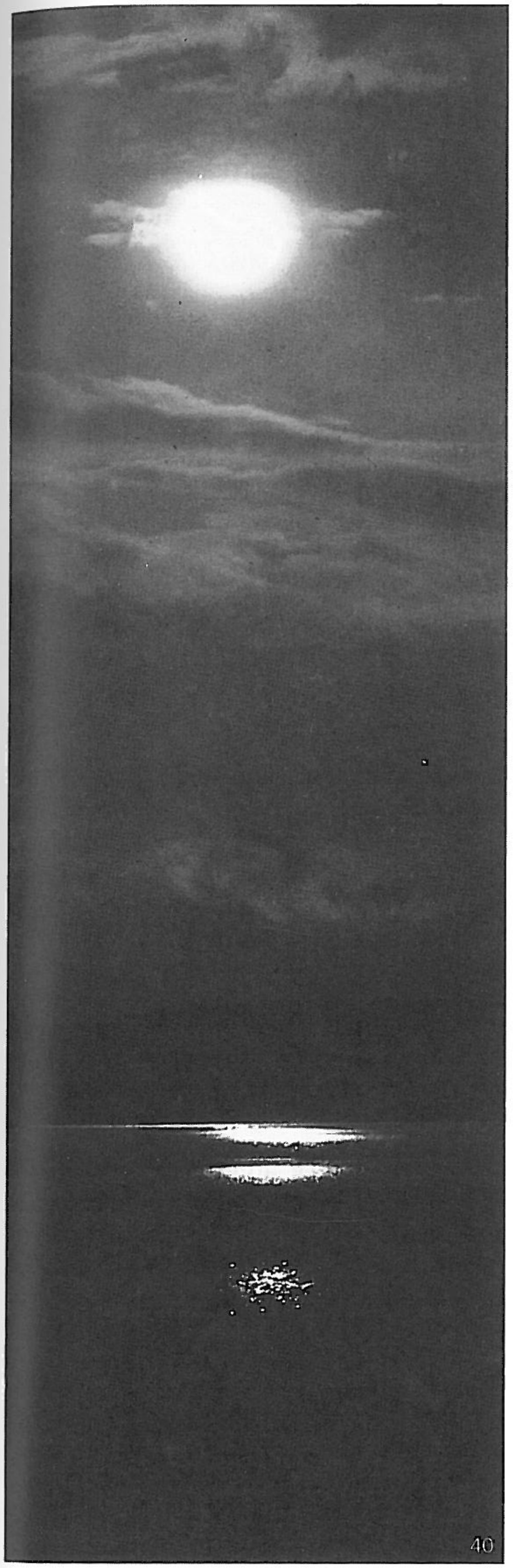
Suddenly I had an image of a green world, half turned towards the sun, leaves cupped to its light, encapsulating it through their templates, into their beings, this modified and ordered sunlight then transmuted by the inordinate variety of creatures and, through plants and animals, to man. Thus all life now, the residues of all life past, the transformations of all life in all time, all creatures and all men, are based upon the chloroplast, turned to the sun, arresting and ordering its energy as it passes to disorder. It is, as it were, as if the leaf said to the sun: "May I use some of your energy before it is degraded?" And the sun assented. So the leaf took the energy, ordered it into its being, sustained its growth and evolution, and those of all other creatures, before the energy, degraded, was yielded to disorder.

Consternation is an appropriate term to describe my continuing encounters with old but astonishing information. The second of these came, not from a lecture but from a book, *The Fitness of the Environment* by Lawrence Henderson. The most startling statement opens the preface:

> *Darwinian fitness is compounded of a mutual relationship between the organism and the environment. Of this, fitness of environment is quite as essential a component as the fitness which arises in the process of organic evolution; and in fundamental characteristics the actual environment is the fittest possible abode of life.*

This conception then precedes the Darwinian theory in that it postulates evolution of matter to create the fitness of life and its evolution. It supplements natural selection, for not only is the successful organism adapted to the environment, but the environment is fit for the organism. "Fit" involves the assumption of the environment's provisions of opportunity for the organism, the latter is a response to this opportunity. Henderson supports his proposition by elaborating upon the characteristics of carbon, hydrogen and oxygen—to which George Wald would add nitrogen, including then those elements which constitute 99% of all organisms. But, of all matter which exhibits fitness, Henderson chooses the oceans and water:

> *The fitness of the environment results from characteristics which constitute a series of maxima—unique or nearly unique properties of water, carbonic acid, the compounds of carbon, hydrogen and oxygen and the ocean—so numerous, so varied, so nearly complete among all things which are concerned in the problem, that together they form certainly the greatest possible fitness. No other environment consisting of primary constituents, made up of other known elements, or lacking water and carbonic acid, could possess a like number of fit character-*



istics, or in any manner such great fitness to promote complexity, durability, and the active metabolism in the organic mechanism we call life. *

The oceans, three-quarters of the earth's surface, are a great stable body with little variation in temperature and alkalinity and with both richness and constancy of chemical composition. It was here in this realm where sunlight penetrates, but beyond the range of toxic ultraviolet rays, that life could and did emerge. Here in this ancestral home life was created. The body fluids of simple marine organisms are all but identical with seawater. The blood of man is similar to the seas of earlier times. Loren Eiseley has said that the dimension of man's emancipation from the sea is the length of that cell which separates him from its source of blood, the ancient brine. All creatures are essentially aqueous solutions confined in membranes.

Ecologists describe the thin film of life covering the earth as the *biosphere,* the sum of all organisms and communities, acting as a single superorganism. Persuasive evidence for this derives from the oceans themselves—Henderson observed a marked correspondence between the regulatory mechanisms of the ocean and organisms, accomplished by temperature regulation through evaporation and regulation of alkalinity.

> *It is at least worthy of mention that the regulation of the ocean in general bears a striking resemblance to a physiological regulatory process, although such physiological processes are supposed to be the result of organic evolution alone.* **

While the pyramid of life is dependent upon the sunlight captured by the chloroplast, the great work performed by the sun—a gigantic multiple of that employed in photosynthesis—is the evaporative phase of the hydrologic cycle in which water is transmuted into vapor, elevated and then precipitated as rain or snow, sustaining those terrestrial creatures who have escaped from the sea but who are still dependent upon it.

Think then of the great work of the sun, distilling, raising and dropping the rain upon the waiting creatures on the land, who stand like dams across the water's implacable path, encapsulating it to form the larger part of their beings, ordering it with their unique templates—reservoirs of sea rain temporarily arrested on its inexorable gravitational path to the sea, but forever raised again and again to sustain and replenish those erstwhile sea creatures, membranes enclosing a briny solution.

The man who aspires to translate is limited not only by his knowledge of language but of substance. In wishing to bring a modicum of natural science to the planning process, I am, like most other planners, seriously hampered by ignorance of the subject. Yet, truly, who would expect to find that major world processes depend upon inconspicuous creatures called Foraminifera or Azotobacter. But indeed they do.

Four elements, abundant in the world—carbon, hydrogen, oxygen and nitrogen—constitute all but one per cent of living creatures. Their characteristics as well as their abundance constitute the best evidence of the fitness of the environment. These elements are indeed abundant: carbon as CO_2 in the atmosphere, in rocks, in the oceans and, above all, in the living; hydrogen and oxygen in the hydrosphere, oxygen 20% and nitrogen 78%, by volume, of the atmosphere.

Why should these four elements play such a central role in life? In his introduction to a new edition of Henderson's book, the biochemist George Wald answers this question—"I should say, because they are the smallest elements in the periodic system that achieve stable electronic configurations by gaining respectively 1, 2, 3 and 4 electrons. The special point of gaining electrons is that this is the mechanism by which chemical

*Lawrence J. Henderson, *The Fitness of the Environment,* The Macmillan Company, New York, 1913, page 272.

***The Fitness of the Environment,* p. 188.

bonds, hence molecules, are formed. . . The point of these being the *smallest* such elements is that they tend to form the tightest and most stable bonds, and with few exceptions they alone form multiple . . . bonds. Why is that last thing important? Because, for example, in carbon dioxide the elements carbon and oxygen, by forming double bonds with one another, O=C=O, satisfy all their tendencies for chemical combination. As a result, independent molecules of carbon dioxide go off in the air as gas and dissolve in water; and from them plants can derive their substance, and animals by eating plants can derive theirs."*

Carbon, dominant in the chemistry of creatures, entered the primeval world in methane, but was oxidized to CO_2 and water. According to Hutchinson, "The resulting CO_2 could not accumulate on a wet planet . . . and so formed vast beds of limestone. The hypothetical pre-Cambrian limestone is to be regarded as the source of all CO_2 that has subsequently entered the atmosphere."**

In the modern earth carbon dioxide and thus carbon is found in the oceans, atmosphere and the rocky mantle and fixed in the biosphere. Carbon dioxide is involved in a great cycle, relatively imperfect. It begins with volcanic action releasing original and secondary sources of CO_2 that tend to concentrate in the oceanic depths. This material must be returned to the system by repeated volcanism if the cycle is to be completed. But it appears that more CO_2 is being fixed by the pelagic foraminifera in deep oceanic basins than is being returned to the system by volcanism—with a resulting net deficit. CO_2 is involved in smaller cycles—normally at the interfaces between the oceans, plants, soil and the atmosphere.

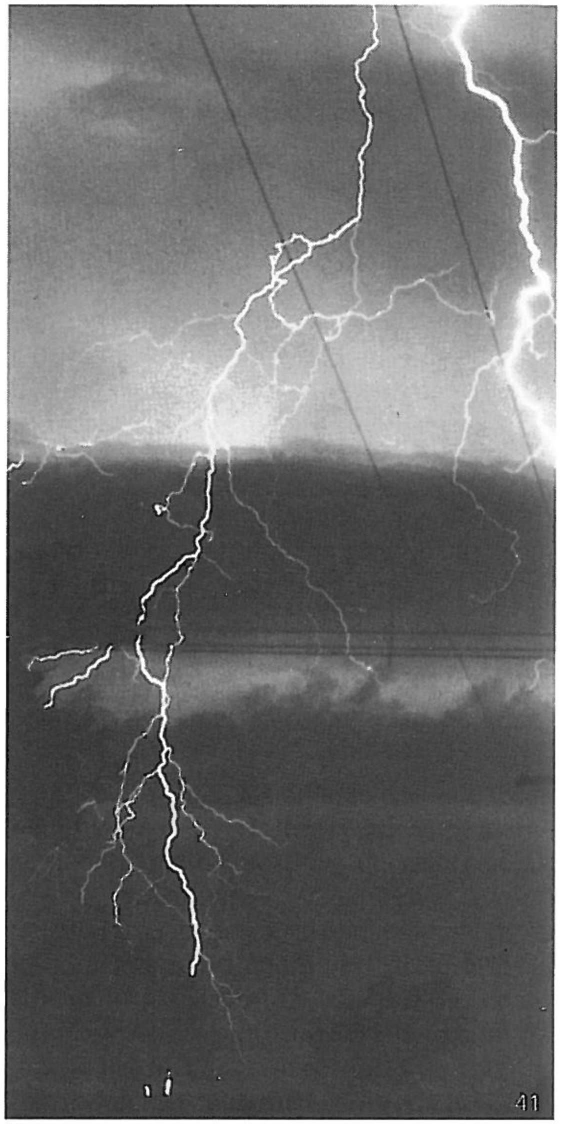
The oceans act as a major regulator in the system. CO_2 is fixed through plant photosynthesis; this is taken from the oceans, but equilibrium has been maintained with the atmosphere during geologic time. In turn, respiration of plants and animals and decomposition add CO_2 to the ocean, which tends to come into equilibrium with the atmosphere.

Carbon is the fire at the heart of life. It has the unequaled ability to form complex compounds, exceeding in number all other chemical compounds, which it derives from its ability to form chains and rings of atoms.

It is this carbon—central to life, emerging from methane, fixed in beds of ancient limestone, released by volcanism and by solution as CO_2—which is used by plants again and again but is increasingly fixed in the oceanic foraminifera and lost to the system unless returned by volcanism. There is, however, a new element in the system—the enormous production of CO_2 as a byproduct of combustion—which has vastly increased the level of CO_2 with the result that ocean and atmosphere are not now in equilibrium.

It is the union of carbon and hydrogen that produces the hydrocarbons. Hydrogen, the first element, the primeval atom, is the basis of physical and thus biological evolution. It is as important as a constituent of water as it is a partner in the hydrocarbons. It is the hydrogen bond in the water molecule which provides the essential qualities of the latter, "its great surface tension, cohesiveness, high boiling point, high heat of vaporization."*** And those are the attributes that Henderson used to identify water as the most fitting of the attributes of the environment.

Oxygen exists as 20% of the atmosphere. In the form of oxides it permeates the oceans, the lithosphere and life. It is the input in animal and plant respiration and decomposition, it is a net product of photosynthesis over time. It is the union of oxygen and hydrogen which constitutes water and gives it the essential attributes it exhibits; it is the union of oxygen and carbon which constitutes that most essential compound, carbon



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dioxide. We need oxygen for survival.

While 78% of the atmosphere consists of nitrogen, it is in rocks that it is most abundant, constituting five-thousandths by weight. A considerable quantity of nitrogen is fixed from the atmosphere by organisms. According to Eugene Odum this may be as much as two hundred pounds per acre in cultivated areas, from one to six pounds per acre in the biosphere as a whole. Unlike the cycle of carbon dioxide and, as we shall see, phosphorus, the nitrogen cycle is relatively perfect. The major source of free nitrogen is the atmosphere. This is made available to

*George Wald in *The Fitness of the Environment* by Lawrence J. Henderson, Beacon Press, Boston, 1958, p. xx.

**G.E. Hutchinson, The Biochemistry of the Terrestrial Atmosphere, in *The Earth as a Planet,* edited by G.P. Kuiper, University of Chicago Press, Chicago, 1954, p. 388.

***George Wald, in Henderson, 1958, p. xxii.

plants by photochemical fixation, by nitrogen-fixing bacteria and algae, and, it is speculated, by lightning. As nitrates it is used in the protein synthesis of plants, animals and bacteria. The wastes of protein synthesis are reduced by decomposers to amino acids and organic residues. These are transformed by bacteria into ammonia, then to nitrites and finally to nitrates available once more for plant synthesis.

Nitrogen is added to the cycle from igneous rocks and is a product of volcanic action. There are losses to oceanic sediments, some of which are retrieved from marine birds and fishes.

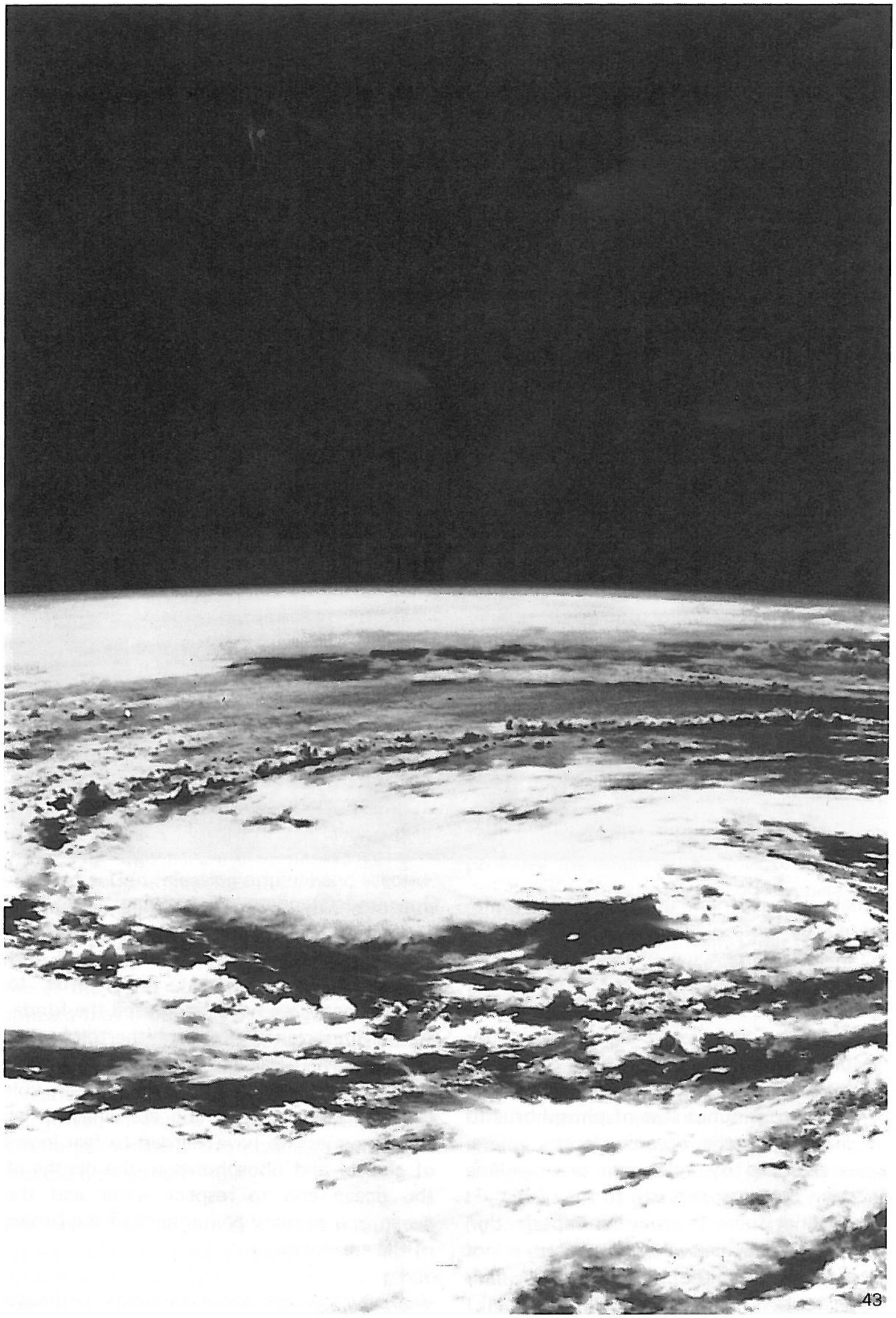
In the cycles of oxygen, hydrogen and carbon, living organisms play an important part, but it is nonspecific—that is, all photosynthetic plants perform the same role in the oxygen-carbon dioxide cycle. But in the nitrogen cycle one finds unique groups of specialists who perform indispensable roles. Without them the cycle of nitrogen would be imperfect and the world of life would be limited to those creatures that could employ nitrogen in available non-organic form.

These indispensable creatures, performing their vital role in the nitrogen cycle, deserve to be household words, man's great heroes. Yet sadly those who named them had no thought of public honor and familiarity and called them Azotobacter and Clostridium, Rhizobium and Nostoc.

There remains an unidentified one per cent of matter constituted in organisms. Within this small proportion are many essential elements, including the trace metals, but one of these must be selected for particular attention because of the nature of its cycle. Phosphorus, essential for life, is involved in a system more simple, yet more critical, than nitrogen. The major reservoir is again in the rocks and deposits; it exists in the oceans and in organisms. Like nitrogen it is employed in protein synthesis of plants and animals. The reservoir in the rocks is supplemented by volcanic apatite and from the excrement and residues of marine birds and fishes. As dissolved phosphate it is used by plants, animals and bacteria, and their excretions, bones and teeth are reduced by phosphatizing bacteria into a form again suitable for protein synthesis. In this cycle there is a continuous loss of phosphorus to the sea and to the oceanic depths where, unless returned by volcanism or upwelling by ocean currents, it is lost to the system. It appears that there is today an imperfection in the phosphorus cycle and that it is not being returned to the system as fast as it is being consumed.

Our understanding is growing: we have added the four major elements, carbon, hydrogen, oxygen and nitrogen and one important minor element, phosphorus, to our company; we have recognized the fundamental importance of some hitherto obscure and unknown algae and bacteria, Nostoc and Azotobacter; we have recognized that volcanic action and lightning are allies rather than enemies; we have learned to fear losses of carbon and phosphorus to the depths of the ocean and to respect water and the ocean as a primary component of the fitness of the environment.

Can we now see these elements, endlessly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recycled, the same finite source moving from the seas into the air, from rocks into solution, deposited and again raised by volcanism, passing through the streams of life, constituted into protoplasm, in the quick and the dead, mobilized in creatures from the beginning and forever? From the heart of volcanoes, from ancient beds of limestone, from high in the atmosphere or from deep in the seas this matter is endlessly recycled—sustaining life, fit for life.

Our identification, even of the major actors of the biosphere, is far from complete if we forget the encompassing envelope that is our milieu: the atmosphere—that membrane around the earth whose gases pervade the seas and the soil and permeate all living things.

> *It would seem universally admitted that the earth's atmosphere is secondary, as is indicated by the extremely low content of the heavy rare gases . . . if by nothing else. It would also seem clear that the first atmosphere could not have contained much CO_2 . . . . It is also reasonably certain that, initially, it could not have contained free oxygen. The most likely constituents are ammonia, giving rise to nitrogen as hydrogen is lost, and methane, which would be fairly stable in the absence of oxygen.* *

Such is G. Evelyn Hutchinson's description of the early atmosphere. It was in this situation, he hypothesizes, that "surface reactions on solids, [in shallow oceans] probably aluminosilicate clays . . . might provide further . . . opportunities not only for organic synthesis but also for incipient biological organization."**

There seems to be reason to believe that the original forms of life were anaerobic, existing without oxygen. There is indeed speculation that biolumineseence—which is most familiar today in the firefly—is a residue of this period when it was necessary for orga-

*G.E. Hutchinson in ***The Earth as a Planet,*** p. 422.

nisms to expel an oxygen that was toxic. There is a further and more entertaining speculation to the effect that this same primitive bioluminesence was a precursor of the evolution towards the nervous systems of animals and thus of the human brain, the great oxygen consumer. This suggests that the brain is the descendant of an early waste-disposal system.

There subsequently emerged the plant, consuming CO_2 and expelling oxygen. The product of this photosynthesis was an increase in free oxygen, first in the seas and subsequently in the atmosphere. It was this, with water vapor and CO_2, which reduced the toxicity of radiation and enlarged the arena in which life could exist. Thus it was life which modified the atmosphere; and the atmosphere in turn not only protected but encouraged and sustained life.

Let us think then of the atmosphere as the skin of the earth, the outer membrane of the biosphere. Let us think of the primeval earth when this thin film rose from the oceans, the exhalations of plants and animals, oxygen and carbon dioxide, which with water vapor, passed the life-giving light, but excluded the destroying rays. This bubble expands, rising from the sea to encompass the land and all the earth. This membrane is evolving, as truly as are the skins of creatures, elaborating to sustain more and more complex life. Now it covers us, raised high, this atmosphere of life, our outer membrane, the breaths of ancient lives, protecting and sustaining us, warming, shading, washing with rain, reverberating with thunderstorms charging the earth, modulating the light through days and changing seasons, source of climate and of weather, making the distant stars twinkle—this atmosphere which permeates us.

The chloroplast in the oceans and on land created that atmosphere which could sustain life. It is matter, water, the leaf, and the decomposers, which, with the sun, are the basis for all life now, all life past and the orderings accomplished by all life in all time. The creation of a life-sustaining atmosphere was one of the most important constituents of this evolutionary process.

Henderson observed that the regulatory powers exhibited by the ocean over temperature and alkalinity demonstrated a remarkable similarity to the homeostatic powers of an organism. In man, the maintenance of health permits only a very, very narrow deviation from a temperature of 98.6°F. The level of alkalinity in human blood, determined by CO_2 (as in the ocean) shows an equally small tolerance—forty-four parts per billion are associated with health, one tenth of a part per billion with coma and death.

The oceans maintain uniformity of alkalinity through the same action of CO_2, which tends towards equilibrium with the atmosphere. The temperature of the ocean maintains equilibrium from its mass, from the exceptionally high number of calories water requires to change temperature at all and by evaporation and convection. Both the organism and the oceans demonstrate similar mechanisms which maintain dynamic equilibrium. Does the atmosphere exhibit similar mechanisms? Is it also in some way organic and evolutionary?

Plants expel oxygen as a by-product of metabolism and consume it in respiration; animals consume oxygen and respire CO_2. Thus the availability of CO_2 limits plants; the availability of oxygen and plant protein limits animals and, when the available CO_2 reaches the lower limits, temperature regulation also inhibits plant growth. Here again is the same self-regulating mechanism as that exhibited by the oceans, described as "organic" by Henderson. The atmosphere, too, then must qualify for this description; it is organic and evolutionary.

As we absorb these fundamental truths, surely they change our image of the world and ourselves. When we see the atmosphere and the hydrosphere as evolutionary, exhibiting the characteristics of organisms, responsive, having self-regulating mechanisms, our conception of the biosphere must expand to include not only the film of living creatures on the earth, but the atmosphere above the extensive oceans as well. Water and air move through all life, the air surrounds and permeates us, the waters replenish that cistern which is ourselves. "The whole evolutionary process, both cosmic and organic, is one, and the biologist may now rightly regard the universe in its very essence as biocentric."* But not necessarily anthropocentric.

But life without death is unthinkable. Given sunlight, nutrients, water and suitable habitats, a colony of plants would so proliferate as to incorporate all available nutrients within itself. As life is defined not only by irritability or responsiveness but by growth, with no further nutrients available, no further life would be possible. Yet, non-growing organisms, encapsulating their own substances without release for use and re-use by the system would starve and die.

So death is necessary as is the decomposition of wastes and the matter of recent life. When the pathogens and the decomposers reduce the substances of living tissues and reconstitute them into forms usable by other organisms, these—with sunlight and water—make possible the creation of new life, which, by mutation and natural selection, ensures evolution.

The prospect of death begins with life, the span is written in the genetic code. In life the parasites, pathogens and age make incursions within their host while the environment and predators attack it from without. The agents of disease proceed towards death. This is not an instant but a process, in which the carrion eaters, scavengers, insects and their larvae, worms, fungi and bacteria reduce the matter into reusable forms.

Life continues, creatures live, propagate, die,

**Hutchinson, p. 424.

*Henderson, 1913, p. 312.

DECOMPOSERS*

*W. Irvine, Microphotographs of sewage fungus and other micro-organisms, ***The Biology of Polluted Waters*** by H.B.N. Hynes, Liverpool University Press, 1960, p. 96.

their progeny contain mutants and so evolution proceeds. The agents of disease are involved in their death and, with the decomposers, in their destruction and recycling in this return phase of matter to sustain life.

Here the eternal materials of the finite earth, increased by the residues of long dead encapsulations of ancient sunlit creatures, move again and again through plants, animals, wastes and the products of death, constantly recycled by the decomposers.

Decomposers have been described as the return stroke of matter in the cycles of life, some of them are illustrated—not with any hope of widespread public recognition but merely to give some shape and dimension to these indispensable organisms. Few indeed will wish to know their names but these do deserve our honor. The first is an alga—*Stigeoclonium tenue*—followed by *Fusarium aqueductum* and *Carchesium polypinum.* Next is *Zoogloea ramigera* alone and then mixed with *Sphaerotilus natans,* followed by *Beggiatoa alba* and *Apodya lactea*. A massive form of *Zoogloea* follows and in the next illustration is shown highly magnified. The penultimate example is *Leptothrix ochracea* while the last is *Gallionella ferruginea.*

Our list of characters, although still only partial, has become too large for the identification of its essential workmen. In the absence of specific recognition and salutation it might be well to extend a general air of appreciation and conciliation to all nature or even better, to begin to understand and act from understanding.

Darwin advanced the conception of biological evolution with natural selection as its primary mechanism. Henderson observed that the earth was peculiarly suited to the evolution of matter and of life, of creatures and of man. Both descriptions of fitness are necessary; they are complementary. Biological evolution still continues, but it does not respond easily to voluntary manipulation while the environment is in a constant flux, inevitably changed by the presence of organisms.

The environment—land, sea, air and creatures—does change; and so the question arises, can the environment be changed intentionally to make it more fit, to make it more fitting for man and the other creatures of the world? Yes, but to do this one must know the environment, its creatures and their interactions—which is to say ecology. This is the essential precondition for planning—the formulation of choices related to goals and the means for their realization.

In the long view one can see the great procession of the evolution of matter and of life, the history and direction of time and life forms. From the precision of evidence comes the poetic license which Wald invokes to speak of the yearnings of atoms as they evolved from hydrogen to the heaviest elements, the compounds as they evolved to the amino acids, unicellular creatures as they evolved to multifarious forms, the yearnings of the earliest tree shrews and their descendants that lead to man, and not least, the yearnings of man.

I can think of no better way of looking at the world and its processes than as if these were a timeless yearning, occurring in a milieu with a proclivity for evolution and for life, in which the environment is fit and may be made more fitting—in which the test is the capacity to adapt the environment and one's self.

There can be no present without a past, no future without both. That which is is only comprehensible in terms of what was. That which was may explain that which is, but cannot predict that which will be.

There is elaborate evidence of that which was in time past. To this we can attend. Much that has been has left evidence of its being. It is written in geomorphology, anatomy, physiology, morphology and cultural

history, although some is too faint to be read. The place and the creature are textbook and teacher, they can speak to him who would and can read.

Perhaps the greatest conceptual contribution of the ecological view is the perception of the world and evolution as a creative process. This can be simply demonstrated by examining the difference between the early earth and the planet as we know it today. Take the mind back to the sterile orb, racked by volcanic action, still lacking oceans. Upon this the energy of the sun fell and an equal amount of energy was lost; this energy was degraded in the process.

Think now of the oceans which developed upon the earth. The sun's rays power both evaporation itself and the transport of the water vapor, which is precipitated upon the earth, moving from high to low elevation. In this process the same energy is employed as before, but work is being performed; the water at higher elevations has a greater potential energy than that in the oceans. Yet all water is proceeding towards its base level as surely as all energy is destined to be degraded. The water acts on land surfaces, and through erosion and sedimentation changes these surfaces towards equilibrium, a condition of repose in which matter moves from a condition of greater to lesser randomness. But, as Paul Sears notes, "while inorganic systems of matter and energy tend towards repose, those which involve life exhibit a countertendency so long as energy is available to keep them going."*

While entropy or degraded energy in any system must increase, in life systems and the orderings that they accomplish, there is evidence, not of degradation, but upgrading, the countertendency which Sears describes. "Energy impinging on living communities and stored in carbon compounds sustains a variety of forms of life, promoting their individual and group organization, enhancing the capacity of the habitat to sustain life, regulating the economy of water movement and chemical transformations—in short doing work."** In this energy is employed with matter through living processes. The energy is temporarily entrapped; it will inevitably be lost to entropy but it will also be replaced. Meanwhile the living creatures persist, evolve and in their beings and their modifications to the earth, act to raise matter to higher orders. This tendency, which is the sum of all life and all time, and the orderings which these have accomplished, is described as *negentropy.* Perhaps it can be given the more affirmative and colloquial title of *creation*—the world's creativity.

We can now see the earth as a process in which energy continuously falls, which inevitably will be degraded, but which through physical processes and life is arrested and entrapped in creatures, raising matter, as evolution proceeds, to higher and higher order. We can see the ordering of physical processes accomplished by precipitation, erosion and sedimentation, volcanism and uplifting, lightning and evaporation, all reducing the randomness of matter essential to this ordering: but overwhelmingly the plant is seen to be the basic agent which arrests and entraps sunlight, the basic agent for the ordering that is negentropy and creation.

Entropy is the rule, it demands its price; all energy is destined to be degraded but physical systems are becoming more ordered on earth, while life systems continue to evolve towards greater order, greater complexity, less randomness—towards negentropy. Abstract, absolute entropy would be that condition when all energy would be degraded, random, simple, uniform, disordered, unable to perform any further work. In contrast, idealized negentropy would exhibit high order, complexity, diversity, uniqueness, ability to perform work. Is this not a description of life and the direction of evolution—it is negentropic—creative.

Can one then imagine negentropy as a tide of ordering, moving deferentially against the force of entropy, paying its tithe, evolving from the order of the nonliving into life, from simple to complex life, from uniformity to diversity, from a small number to an infinitude of species, aspiring to dynamic equilibrium, always imperiled as evolution moves forward? Within this path the cycles of life, death and decay recycle the increasing storehouse of ordered matter, wrested from entropy, through the system. Within the biosphere the creatures in communities and their habitats increase in complexity, in the nature of their symbiotic relationships, in negentropy, evolving—as Teilhard de Chardin has suggested—towards increasing consciousness.

We may now be quite sure, that as men we depend upon the sun, the major elements and compounds, water, the chloroplast and the decomposers. With this new conviction we now turn to the sun and say, "Shine that we may live." We can contemplate matter and say, "From this is the universe, the world and life made." To the oceans we say, "Ancient home, nourish us with water." As the clouds rise from the sea, rains fall and rivers flow, we say, "Nourish us from the sea that we may live." Look to the plants, say, "Through you we breathe, through you we eat, through you we live." To the atmosphere we ask "Protect and sustain us." Hold in your hand some soil, know that the essential decomposers are there and say, "Be and work that we may be."

When we do these things, and say these things with understanding, we have crossed into another realm—leaving behind the simple innocence of ignorance. We can see the world more clearly now, our allies and ourselves. We have formulated a rudimentary value system and we are further on the path to the formulation of a workman's code, the view of the good steward.

*Paul B. Sears, ***The Ecology of Man,*** Condon Lectures, University of Oregon Press, 1957, p. 44.

**Sears, p. 45.

Nature in the Metropolis

The discussion on matter and cycles may have appeared as an unnecessary excursion into biophysical science. Was it really necessary? Consider. The arguments that are normally mobilized in plaintive bleeding-heartism are clearly inadequate to arrest the spread of mindless destruction. Better arguments are necessary. The accumulation of some evidence of the ways of the working world produces an effective starting point. In the remarkably unsuccessful early years of my battles against the philistines I found that proffering my palpitating heart accomplished little remedy but that the diagnostic and prescriptive powers of a rudimentary ecology carried more weight, and had more value.

If we can assume that the reader has left the metaphorical space capsule with the same understanding of some basic physical and biological laws as the astronaut, we can assume that his interest in nature is not even remotely sentimental. We can now assume his solicitude for these indispensable processes as intelligent self-interest. We can also expect that the initial proposition now evokes a deeper understanding and acceptance—nature can be considered as interacting process, responsive to laws, constituting a value system, offering intrinsic opportunities and limitations to human uses. Now better armed, we can take our knowledge of nature as process and apply this to a problem—to discern the place of nature in a metropolitan region.

Some years ago I was asked to advise on which lands in the Philadelphia metropolitan region should be selected for open space. It became clear at the onset that the solution could only be obscured by limiting open space to the arena for organized sweating; it seemed more productive to consider the place of nature in the metropolis. In order to conclude on this place it appeared reasonable to suggest that nature performed work for man without his investment and that such work did represent a value. It also seemed reasonable to conclude that certain areas and natural processes were inhospitable to man—earthquake areas, hurricane paths, floodplains and the like—and that those should be prohibited or regulated to ensure public safety. This might seem a reasonable and prudent approach, but let us recognize that it is a rare one.

Consider that if you are required to design a flight of steps or a sidewalk there are clear and stringent regulations; there are constraints against the sale of cigarettes and alcohol to minors, society reacts sternly to the sale or use of narcotics and there are strong laws to deter assault, rape and murder. And we should be thankful indeed for these protections. But there is no comparable concern, reflected in law, that ensures that your house is not built on a floodplain, on unconsolidated sediments, in an earthquake zone, hurricane path, fire-prone forest, or in areas liable to subsidence or mudslides.

While great efforts are made to ensure that you do not break an ankle, there are few deterrents to arrest the dumping of poisons into the sources of public water supply or their injection into groundwater resources. You are clearly protected from assault by fist, knife or gun, but not from the equally dangerous threats of hydrocarbons, lead, nitrous oxides, ozone or carbon monoxide in the atmosphere. There is no protection from the assaults of noise, glare and stress. So while a handrail may be provided for your safety and convenience by a considerate government, you may drown in a floodplain, suffer loss of life and property from inundation of coastal areas, from an earthquake or hurricane; the damage or loss of life could be due to criminal negligence at worst and unpardonable ignorance at best, without the protection of governmental regulation or of laws.

It clearly should be otherwise; there is a need for simple regulations, which ensure that society protects the values of natural

processes and is itself protected. Conceivably such lands wherein exist these intrinsic values and constraints would provide the source of open space for metropolitan areas. If so, they would satisfy a double purpose: ensuring the operation of vital natural processes and employing lands unsuited to development in ways that would leave them unharmed by these often violent processes. Presumably, too, development would occur in areas that were intrinsically suitable, where dangers were absent and natural processes unharmed.

The formulation of these regulations requires no new science; we need move no nearer to the threshold of knowledge than the late 19th century. We can initially describe the major natural processes and their interactions and thereafter establish the degree to which these are permissive or prohibitive to certain land uses. This done, it will remain with the government and the courts to ensure our protection through the proper exercise of police power.

Before we move to this objective it is necessary to observe that there are two other views. They must be examined if only to be dismissed. The first is the economist's view of nature as a generally uniform commodity—appraised in terms of time distance, cost of land and development and allocated in terms of acres per unit of population. Nature, of course, is not uniform but varies as a function of historical geology, climate, physiography, soils, plants, animals and—consequently—intrinsic resources and land uses. Lakes, rivers, oceans and mountains are not where the economist might want them to be, but are where they are for clear and comprehensible reasons. Nature is *intrinsically* variable.

The geometric planner offers another alternative, that the city be ringed with a green circle in which green activities—agriculture, institutions and the like—are preserved or even introduced. Such greenbelts, where enforced by law, do ensure the perpetuation of open space and in the absence of an alternative they are successful—but it appears that nature outside the belt is no different from that within, that the greenbelt need not be the most suitable location for the green activities of agriculture or recreation. The ecological method would suggest that the lands reserved for open space in the metropolitan region be derived from natural-process lands, intrinsically suitable for "green" purposes: that is the place of nature in the metropolis.

A single drop of water in the uplands of a watershed may appear and reappear as cloud, precipitation, surface water in creek and river, lake and pond or groundwater; it can participate in plant and animal metabolism, transpiration, condensation, decomposition, combustion, respiration and evaporation. This same drop of water may appear in considerations of climate and microclimate, water supply, flood, drought and erosion control, industry, commerce, agriculture, forestry, recreation, scenic beauty, in cloud, snow, stream, river and sea. We conclude that nature is a single interacting system and that changes to any part will affect the operation of the whole.

If we use water as an indicator of the interaction of natural processes, we see that the forests felled in the uplands may have an identical effect upon the incidence of flood that is accomplished by filling estuarine marshes. Pollution of groundwater may affect surface water resources and vice versa; urbanization will affect the rate of runoff, erosion and sedimentation, causing water turbidity, diminution of aquatic organisms, and a reduction in natural water purification. These, in turn, will result in channel dredging costs, increased water treatment costs and, possibly, flood damages and drought costs.

So we can say that terrestrial processes require water and that freshwater processes are indissoluble from the land. It then follows that land management will affect water, water management will affect land processes. We cannot follow the path of every drop of water, but we can select certain identifiable aspects—precipitation and runoff, surface water in streams and rivers, marshes and floodplains, groundwater resources in aquifers and the most critical phase of these—aquifer recharge. We can now formulate some simple propositions. Simple they are indeed—almost to the point of idiocy—but they are novelties of high sophistication to the planning process and the bulk of local governmental agencies.

Water quality and quantity are related to both land and water management. Floods are natural phenomena and reveal cyclical frequencies; healthy water bodies reduce organic matter and this varies with seasons, turbidity, dissolved oxygen, alkalinity, temperature, and the biotic population; erosion and sedimentation are natural but are accelerated by almost all human adaptations—on a uniform soil, normally the greater the slope, the more the erosion. Groundwater and surface water are interacting—in periods of low precipitation the water in rivers and streams is usually groundwater; soils vary in their productivity for agriculture as a function of texture, organic matter, chemical composition, elevation, slope, and exposure. Marshes are flood storage areas, often aquifer recharges, the homes of wildfowl and both spawning and breeding grounds; the hinterland of a city is the source of the clean air that replaces the pollutants discharged by the city. The rural hinterland also contributes to a more temperate summer climate. Can we use this information to discriminate between lands that should remain in their natural condition, lands that are permissive to certain uses but not to others and those lands that are most tolerant to urbanization—free from danger, undamaging to other values?

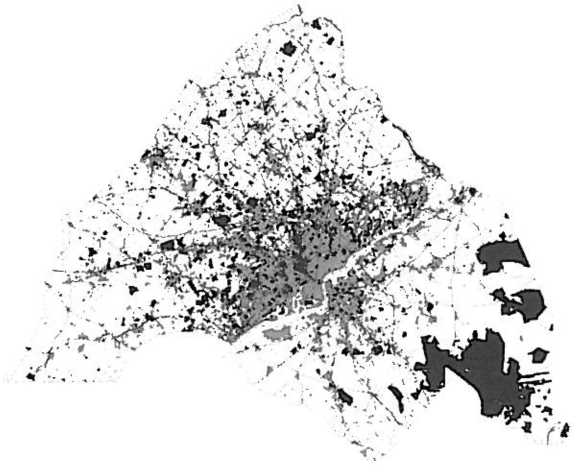
But, first can we afford the indulgence of reserving natural-process lands and regulating development on them in order to capture

their value? Indeed we can: land is abundant. According to the French urban geographer Jean Gottman, perhaps only 1.8% of the United States is urbanized today.* Even within metropolitan regions, there is plenty of land. In the Philadelphia Standard Metropolitan Statistical Area, 3,500 square miles—less than 20%—is urbanized today and even should the population increase to 6,000,000, there would remain at that time 70% or 2,300 square miles of open land.

If so, wherein lies the problem? Simply in the form of growth. Urbanization proceeds by increasing the density within and extending the periphery, always at the expense of open space. As a result—unlike other facilities—open space is most abundant where people are scarcest. This growth, we have seen, is totally unresponsive to natural processes and their values. Optimally, one would wish for two systems within the metropolitan region—one the pattern of natural processes preserved in open space, the other the pattern of urban development. If these were interfused, one could satisfy the provision of open space for the population. The present method of growth continuously preempts the edge, causing the open space to recede from the population center. Geometrically, a solution is not unthinkable. If the entire area of the Philadelphia region were represented in a circle it would have a radius of 33 miles. Present urbanization can be encircled by a 15-mile radius. If all the existing and proposed urbanization for a six-million population and one acre of open space for every thirty persons is encircled, then the radius is 20 miles—only five miles more than the present.

But rather than propose a blanket standard of open space, we wish to find discrete aspects of natural processes that carry their own values and prohibitions: it is from these that open space should be selected, it is these that should provide the pattern, not only of metropolitan open space, but also the positive pattern of development.

*Jean Gottman, ***Megalopolis,*** The Twentieth Century Fund, New York, 1961, p. 26.



EXISTING OPEN SPACE, PHILADELPHIA METROPOLIS

Later on we shall see that there are consistencies in land morphology, soils, stream patterns, plant association, wildlife habitats, and even land use, and that these can well be examined through the concept of the physiographic region. It is premature to employ this concept now. It is enough for the moment to insist that nature performs work for man—in many cases this is best done in a natural condition—further that certain areas are intrinsically suitable for certain uses while others are less so. We can begin with this simple proposition. Moreover, we can codify it. If we select eight dominant aspects of natural process and rank them in an order of both value and intolerance to human use and then reverse the order, it will be seen as a gross hierarchy of urban suitability.

Natural-process Value; Degree of Intolerance	**Intrinsic Suitability for Urban Use**
Surface water	Flat land
Marshes	Forest, woodlands
Floodplains	Steep slopes
Aquifer recharge areas	Aquifers
Aquifers	Aquifer recharge areas
Steep slopes	Floodplains
Forests, woodlands	Marshes
Flat land	Surface water

However, there is an obvious conflict in this hierarchy. The flat land, so often selected for urbanization, is often as suitable for agriculture: this category will have to be looked at more carefully. So prime agricultural land will be identified as intolerant to urbanization and constituting a high social value—all other flat land will be assumed to have a low value in the natural-process scale and a high value for urban suitability.

Within the metropolitan region natural features will vary, but it is possible to select certain of these that exist throughout and determine the degree to which they allow or discourage contemplated land uses. While these terms are relative, optimally development should occur on valuable or perilous natural-process land only when superior values are created or compensation can be awarded.

A complete study would involve identifying natural processes that performed work for man, those which offered protection or were hostile, those which were unique or especially precious and those values which were vulnerable. In the first category fall natural water purification, atmospheric pollution dispersal, climatic amelioration, water storage, flood, drought and erosion control, topsoil accumulation, forest and wildlife inventory increase. Areas that provided protection or were dangerous would include the estuarine marshes and the floodplains, among others. The important areas of geological, ecological and historic interest would represent the next category, while beach dunes, spawning and breeding grounds and water catchment areas would be included in the vulnerable areas.

No such elaborate examination has been attempted in this study. However, eight natural processes have been identified and these have been mapped and measured. Each one has been described with an eye to permissiveness and prohibition to certain land uses. It is from this analysis that the place of nature in the metropolis will be derived.

Surface Water (5,671 linear miles)

In principle, only land uses that are inseparable from waterfront locations should occupy them; and even these should be limited to those which do not diminish the present or prospective value of surface water for supply, recreation or amenity. Demands for industrial waterfront locations in the region are extravagantly predicted as 50 linear miles. Thus, even satisfying this demand, five thousand miles could remain in a natural condition.

Land uses consonant with this principle would include port and harbor facilities, marinas, water and sewage treatment plants, water-related and, in certain cases, water-using industries. In the category of land uses that would not damage these water resources fall agriculture, forestry, recreation, institutional and residential open space.

Marshes (173,984 acres; 8.09%)

In principle, land-use policy for marshes should reflect the roles of flood and water storage, wildlife habitat and fish spawning grounds. Land uses that do not diminish the operation of the primary roles include recreation, certain types of agriculture (notably cranberry bogs) and isolated urban development.

Floodplains (339,706 acres; 15.8%)

Increasingly, the 50-year, or 2%, probability floodplain is being accepted as that area from which all development should be excluded save for functions which are unharmed by flooding or for uses that are inseparable from floodplains.

In the former category fall agriculture, forestry, recreation, institutional open space and open space for housing. In the category of land uses inseparable from floodplains are ports and harbors, marinas, water-related industry and—under certain circumstances—water-using industry.

Aquifers (181,792 acres; 8.3%)

An aquifer is a water-bearing stratum of rock, gravel or sand, a definition so general as to encompass enormous areas of land. In the region under study, the great deposits of porous material in the Coastal Plain are immediately distinguishable from all other aquifers in the region because of their extent and capacity. This may well be the single most important unexploited resource in the region. The aquifer parallel to Philadelphia in New Jersey has an estimated yield of one billion gallons per day. Clearly this valuable resource should not only be protected, but managed. Development that includes the disposal of toxic wastes, biological discharges or sewage should be prohibited. The use of injection wells, by which pollutants are disposed into aquifers, should be discontinued.

Development using sewers is clearly more satisfactory than septic tanks where aquifers can be contaminated, but it is well to recognize that even sewers leak significant quantities of material and are thus a hazard.

Land-use prescription is more difficult for aquifers than for any other category as these vary with respect to yield and quality, yet it is clear that agriculture, forestry, recreation and low-density development pose no danger to this resource while industry and urbanization in general do.

All prospective land uses should simply be examined against the degree to which they imperil the aquifer; those which do should be prohibited. It is important to recognize that aquifers may be managed effectively by the impoundment of rivers and streams that transect them.

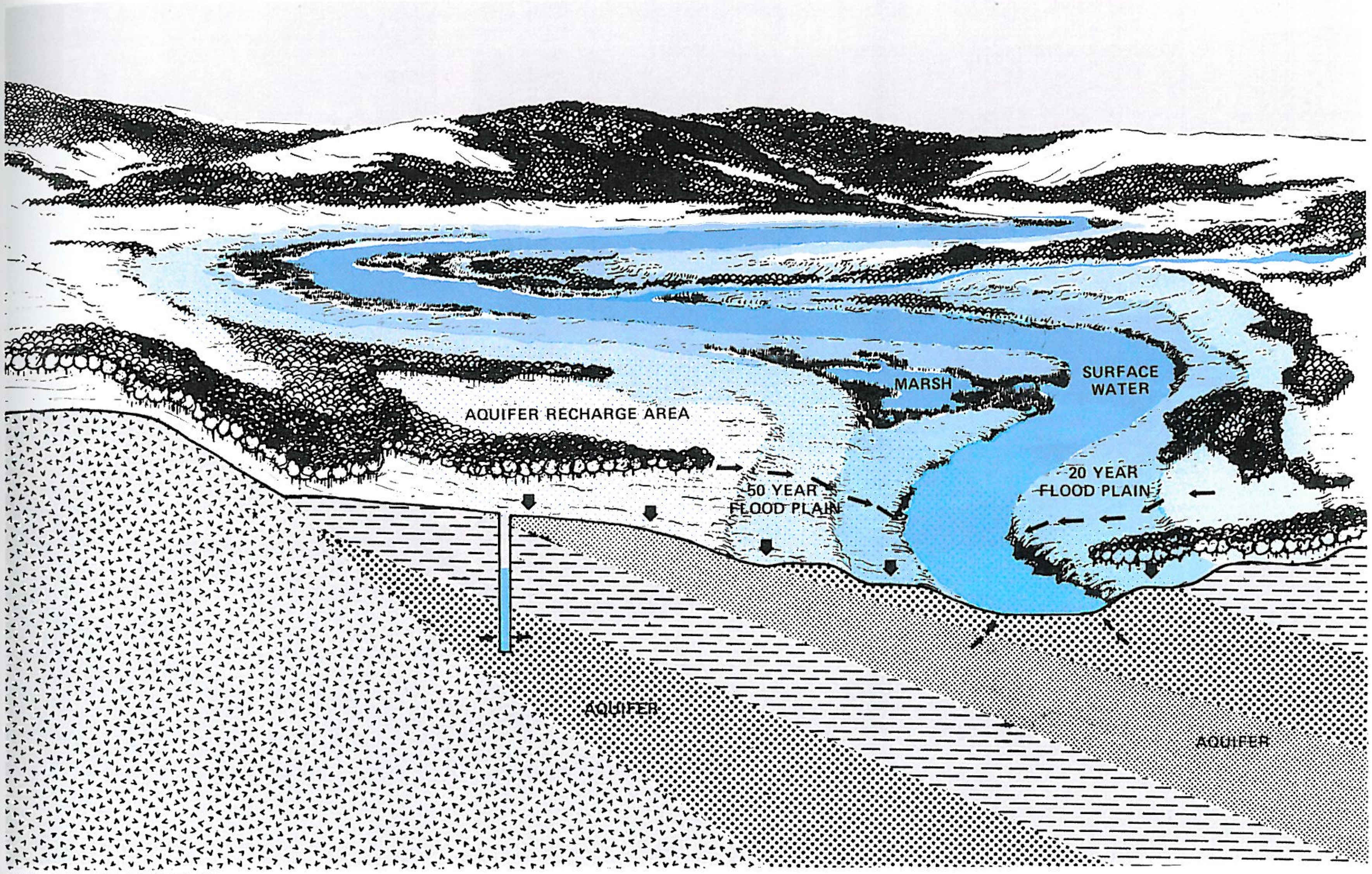
Like many other cities, Philadelphia derives its water supply from major rivers which are foul. This water is elaborately disinfected and is potable. In contrast to the prevailing view that one should select dirty water for human consumption and make it safe by superchlorination, it seems preferable to select pure water in the first place. Such water is abundant in the existing aquifers; it must be protected from the fate of the rivers.

Aquifer Recharge Areas (118,896 acres; 6%)

As the name implies, such areas are the points of interchange between surface water and aquifers. In any system there are likely to be critical interchanges. It is the movement of ground to surface water that contributes water to rivers and streams in periods of low flow. Obviously the point of interchange is also a location where the normally polluted rivers may contaminate the relatively clean—and in many cases, pure—water resources in aquifers. These points of interchange are then critical for the management and protection of groundwater resources.

In the Philadelphia region the interchange between the Delaware River and its tributaries with the adjacent aquifers is the location of greatest importance. The Delaware is foul—frequently it has been observed to lack any dissolved oxygen and was then septic. However, a thick layer of silt, almost thirty feet deep, acts as a gasket and reduces the passage of the polluted river to the adjacent aquifer. It is where an aquifer is overlaid with porous material that percolation from the ground surface will recharge it.

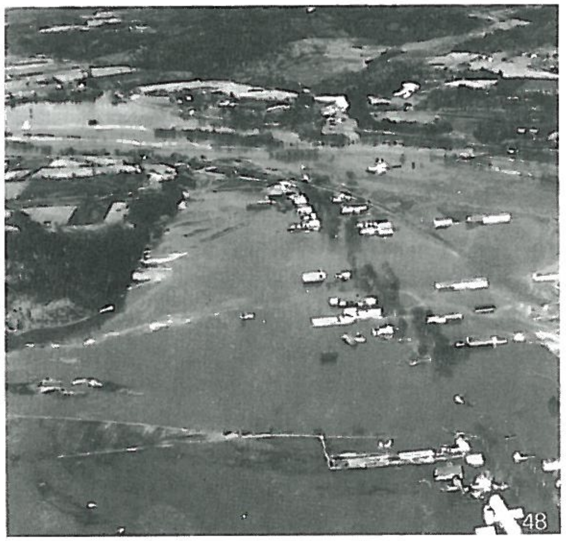
These two considerations, then, should regulate management of these areas. By the careful separation of polluted rivers from the aquifer and by the impoundment of clean streams that transect it, the aquifer can be managed and recharged. By regulating land uses on those permeable surfaces that contribute to aquifer recharge, normal percolation will be allowed to continue.

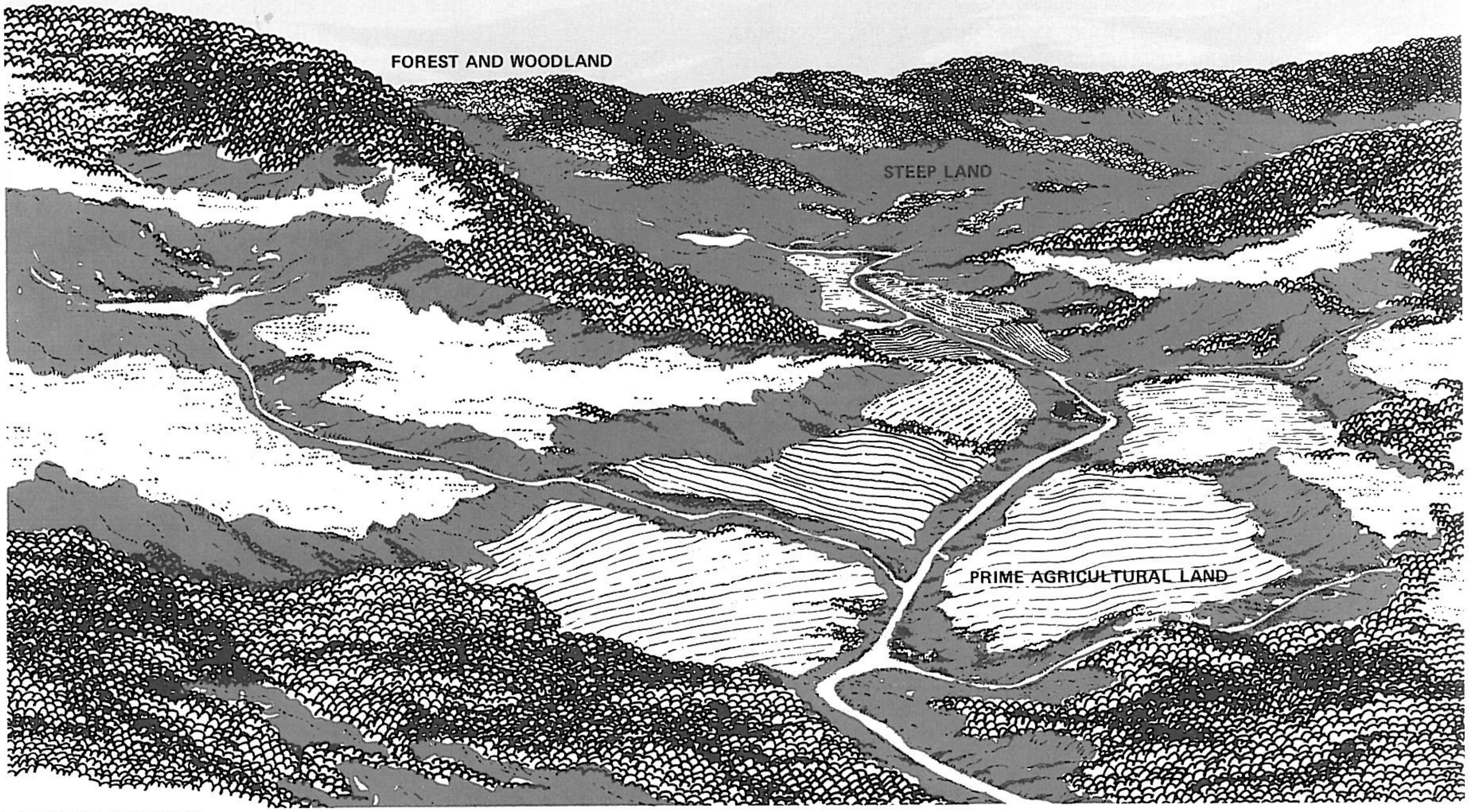


WATER FEATURES


SURFACE WATER


MARSHES


FLOODPLAINS



LAND FEATURES
Steep Lands

Steep lands, and the ridges which they constitute, are central to the problems of flood control and erosion. Slopes in excess of 12° are not recommended for cultivation by the Soil Conservation Service. The same source suggests that, for reasons of erosion, these lands are unsuitable for development. The recommendations of the Soil Conservation Service are that steep slopes should be in forest and that their cultivation be abandoned.

The role of erosion control and diminution of the velocity of runoff is the principal problem here. Land uses compatible with this role would be mainly forestry and recreation, with low-density housing permitted on occasion.

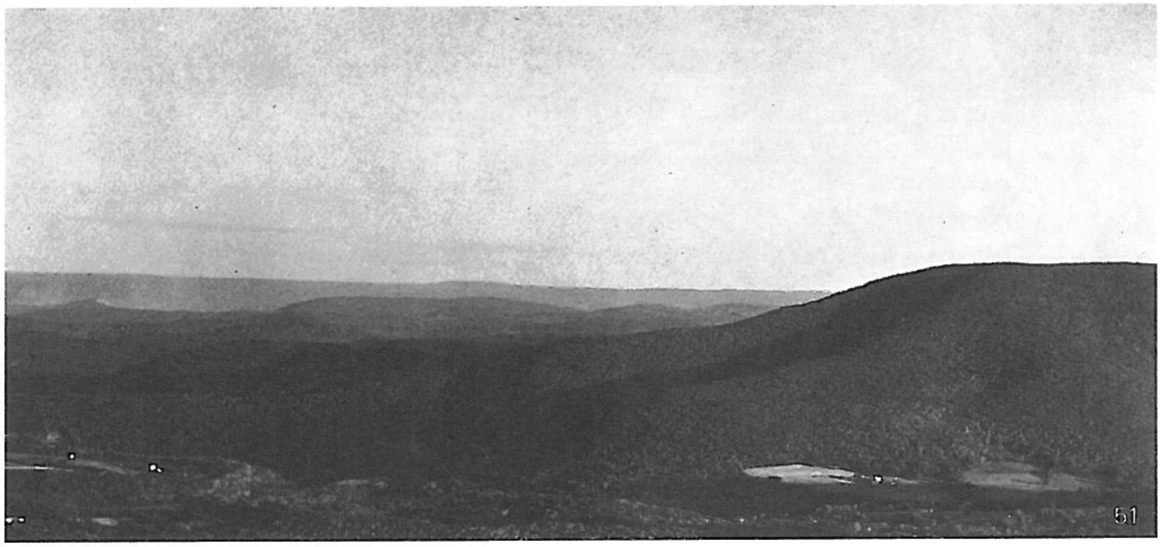
Prime Agricultural Land (248,816 acres; 11.7%)
Prime agricultural soils represent the highest level of agricultural productivity; they are uniquely suitable for intensive cultivation with no conservation hazards. It is extremely difficult to defend agricultural lands when their cash value can be multiplied tenfold by employment for relatively cheap housing. Yet the farm is the basic factory—the farmer is the country's best landscape gardener and maintenance work force, the custodian of much scenic beauty. Mere market values of farmlands do not reflect the long-term value or the irreplaceable nature of these living soils. An omnibus protection of all farmland is difficult to defend; but protection of the best soils in a metropolitan area would appear not only defensible, but clearly desirable.

Jean Gottman has recommended that "the very good soils are not extensive enough in Megalopolis to be wastefully abandoned to non-agricultural uses."* The soils Gottman had in mind are identical to the Prime Agricultural Soils in the metropolitan area.

*Gottman, p. 95.

FORESTS AND WOODLANDS

PRIME AGRICULTURAL LAND



STEEP LANDS

The farmer, displaced from excellent soils by urbanization, often moves to another site on inferior soils. Excellent soils lost to agriculture for building can finally only be replaced by bringing inferior soils into production. This requires capital investment. "Land that is not considered cropland today will become cropland tomorrow, but at the price of much investment."*

In the Philadelphia Standard Metropolitan Statistical Area, by 1980 only 30% of the land area will be urbanized. 70% will remain open. Prime agricultural lands represent only 11.7% of the area. Therefore, given a choice, prime soils should not be developed.

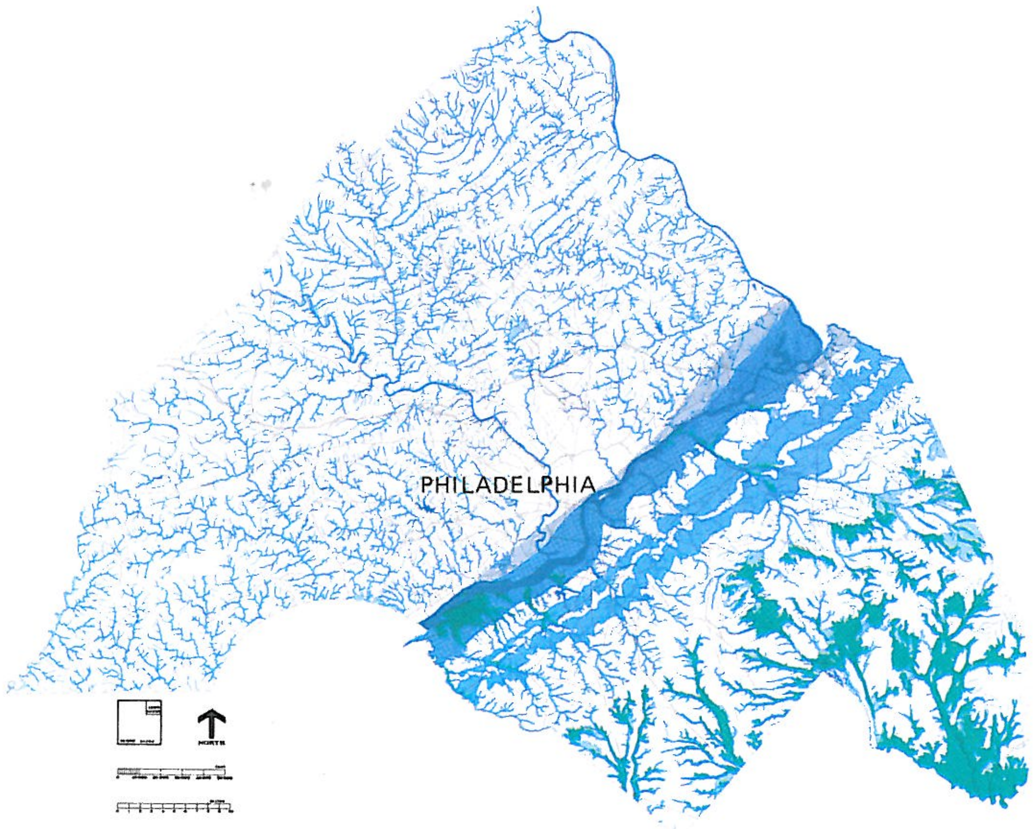
In principle, U.S.D.A. Category 1 soils should be exempted from development (save by those functions that do not diminish their productive potential). This would suggest retirement of prime soils into forest or their utilization as open space—for institutions, for recreation or in development for housing at densities no higher than one house per 25 acres.

Forests and Woodlands

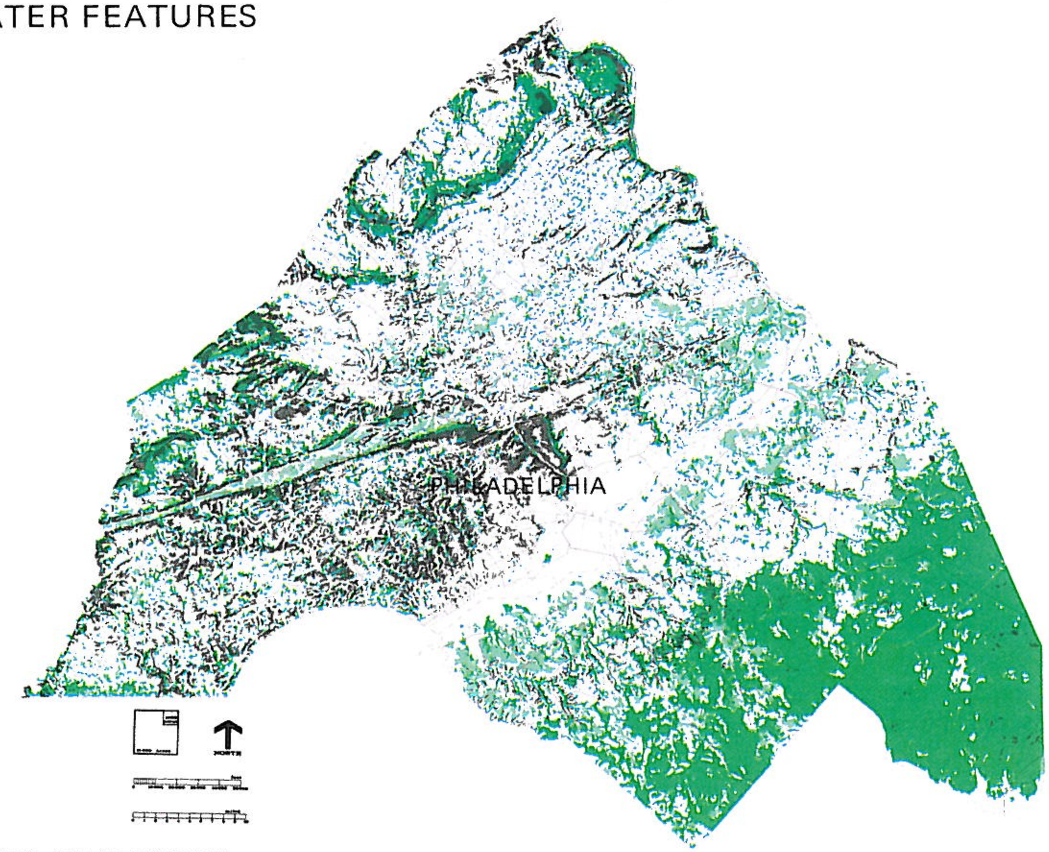
The natural vegetative cover for most of this region is forest. Where present, it improves microclimate and it exercises a major balancing effect upon the water regimen—diminishing erosion, sedimentation, flood and drought. The scenic role of woodlands is apparent, as is their provision of a habitat for game; their recreational potential is among the highest of all categories. In addition, the forest is a low-maintenance, self-perpetuating landscape.

Forests can be employed for timber production, water management, wildlife habitats, as airsheds, recreation or for any combination of these uses. In addition, they can absorb development in concentrations to be determined by the demands of the natural process they are required to satisfy.

*Edward Higbee, Chapter 6, in Gottman, ***Megalopolis,*** p. 326.



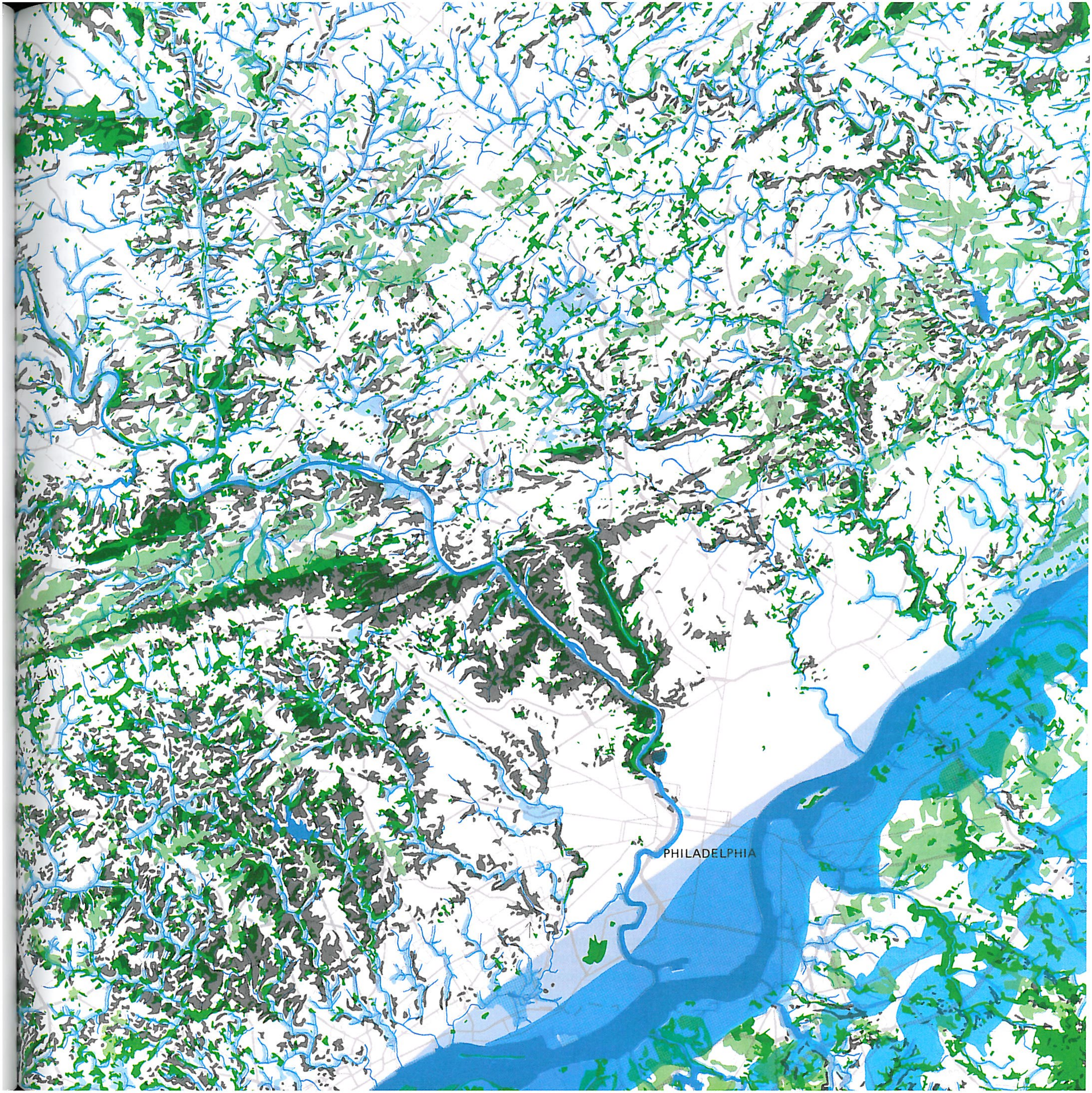
WATER FEATURES



LAND FEATURES

PHENOMENA	RECOMMENDED LAND USES
Surface water and riparian lands	Ports, harbors, marinas, water-treatment plants, water-related industry, open space for institutional and housing use, agriculture, forestry and recreation.
Marshes	Recreation.
50-year floodplains	Ports, harbors, marinas, water-treatment plants, water-related and water-using industry, agriculture, forestry, recreation, institutional open space, open space for housing.
Aquifers	Agriculture, forestry, recreation, industries that do not produce toxic or offensive effluents. All land uses within limits set by percolation.
Aquifer recharge areas	As aquifers.
Prime agricultural lands	Agriculture, forestry, recreation, open space for institutions, housing at 1 house per 25 acres.
Steep lands	Forestry, recreation, housing at maximum density of 1 house per 3 acres, where wooded.
Forests and woodlands	Forestry, recreation, housing at densities not higher than 1 house per acre.

SUMMARY MAP OF WATER & LAND FEATURES FOR PART OF THE METROPOLITAN AREA


PHILADELPHIA

The resolution of atmospheric pollution depends mainly upon the reduction of pollution sources. While discussion of the subject increases in intensity, remedy shows no parallel acceleration, and it may be timely to consider one fact which, if recognized, can at least enhance the future possibility of solution. The city creates the filthy air. Clean air comes from the countryside. If we can identify the major wind directions, particularly those associated with inversion conditions, and ensure that pollution source industries are not located in these critical sectors of the urban hinterland, we will at least not exacerbate the situation.

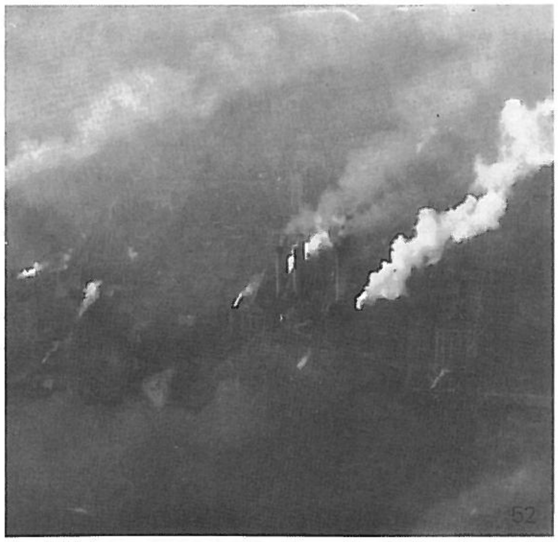
The central phase of air pollution is linked to temperature inversion, during which the air near the ground does not rise to be replaced by in-moving air. Under inversion, characterized by clear nights with little wind, the earth is cooled by long-wave radiation and the air near the ground is cooled by the ground. During such temperature inversions with stable surface air layers, air movement is limited; in cities, pollution becomes increasingly concentrated. In Philadelphia "significant" inversions occur one night in three. Parallel and related to inversion is the incidence of high pollution levels, which occurred on twenty-four "episodes" from 2-5 days in duration between 1957 and 1959. Inversions then are common, as are "high" levels of pollution. The danger attends their conjunction and persistence. Relief, other than elimination of pollution sources, is a function of wind movement to disperse pollution over cities and, secondly, the necessity that in-moving air be cleaner than the air it replaces.

The concentration of pollution sources in Philadelphia covers an area fifteen miles by ten miles with the long axis running approximately northeast. Let us assume sulfur dioxide to be the indicator of pollution (830 tons per day produced), an air height of 500 feet as the effective dimension and an air volume of approximately 15 cubic miles to be replaced by a wind speed of 4 mph, selected as a critical speed. Then one cubic mile of ventilation is provided per mile of windspeed and it is seen to require 3¾ hours for wind movement to ventilate the long axis, 2½ hours to ventilate the cross axis. Thus, the tributary to ensure clean air on the long axis is 15 miles beyond the pollution area, 10 miles beyond for the cross axis. The wind rose for Philadelphia during inversions shows that wind movements are preponderantly northwest, west, and southwest, contributing 51.2% of wind movements; the other five cardinal and intercardinal points represent the remainder.

This very approximate examination suggests that airsheds should extend from 10 to 15 miles beyond the urban air pollution sources in those wind directions to be anticipated during inversion. The width of these belts should correspond to the dimension of the pollution core and, in very approximate terms, would probably be from three to five miles. *Such areas, described as airshed, should be prohibited to pollution source industries.*

Under the heading of atmosphere the subject of climate and microclimate was raised. In the study area the major problem is summer heat and humidity. Relief of this condition responds to wind movements. Thus, a hinterland with more equable temperatures, particularly a lower summer temperature, is of importance to climate amelioration for the city. As we have seen, areas that are in vegetative cover, notably forests, are distinctly cooler than cities in summer—a margin of 10°F is not uncommon. Air movements over such areas moving into the city will bring cooler air. Relief from humidity also results mainly from air movements. These correspond to the directions important for relief of inversion. We can then say that the areas selected as urban airsheds are likely to be those selected as appropriate for amelioration of the urban microclimate. However, to clear air pollution by airsheds, it is important only that pollution sources be prohibited or limited. To relieve summer heat

AIR SHEDS



and humidity, it is essential that these airsheds be substantially in vegetative cover, preferably forested.

The satisfaction of these two requirements, in the creation of urban airsheds as responses to atmospheric pollution control and microclimate control, would create fingers of open space penetrating from the rural hinterland, radially into the city. This is perhaps the broadest conception of natural process in metropolitan growth and metropolitan open-space distribution. Clearly, this proposal directs growth into the interstices between the airshed corridors and suggests that metropolitan open space exist within them.*

Human adaptations entail both benefits and costs, but natural processes are generally not attributed values; nor is there a generalized accounting system, reflecting total costs and benefits. Natural processes are unitary whereas human interventions tend to be fragmentary and incremental. The effect of filling the estuarine marshes or felling the upland forests is not perceived as related to the water regimen—to flood or drought—nor are both activities seen to be similar in their effect. The construction of outlying suburbs and siltation of river channels are not normally understood to be related—nor is waste disposal into rivers perceived to be connected with the pollution of distant wells.

Several factors can be observed. Normal urban growth tends to be incremental and unrelated to natural processes on the site. But the aggregate consequences of such development are not calculated nor are they allocated as costs to the individual developments. While benefits do accrue to certain developments that are deleterious to natural processes at large (for example, clear felling of forests or conversion of farmland into subdivisions), these benefits are *particular* (related, say, to that landowner who chooses to fell trees or sterilize soil), while the results and costs are general. Thus, costs and benefits are likely to be attributed to large numbers of different and unrelated persons, corporations and levels of government. It is unlikely that long-term benefits accrue from disdain of natural process; it is quite certain and provable that substantial costs *do* result from this disdain. Finally, in general, any benefits that do occur—usually economic—tend to accrue to the private sector, while remedies and long-range costs are usually the responsibility of the public domain.

The purpose of this exploration is to show that natural process, unitary in character, must be so considered in the planning process: that changes to parts of the system affect the entire system, that natural processes do represent values and that these values should be incorporated into a single accounting system. It is unfortunate that the information we have on cost-benefit ratios of specific interventions to natural process is inadequate. However, certain generalized relationships have been shown and presumptions advanced as the basis for judgment. It seems clear that laws pertaining to land use and development need to be elaborated to reflect the public costs and consequences of private action. Present land-use regulations neither recognize natural processes—the public good in terms of flood, drought, water quality, agriculture, amenity or recreational potential—nor allocate responsibility to the acts of landowner or developer.

We have seen that land is abundant, even within a metropolitan region confronting accelerated growth. There is, then, at least hypothetically, the opportunity for choice as to the location of development and open space.

The hypothesis, central to this study, is that the distribution of open space must respond to natural process. This conception should hold true for any metropolitan area, irrespective of location. In this particular case study, directed to the Philadelphia Metropolitan Region, an attempt has been made to focus on the fundamental natural processes that show the greatest relevance to the problem of determining the form of metropolitan growth and open space.

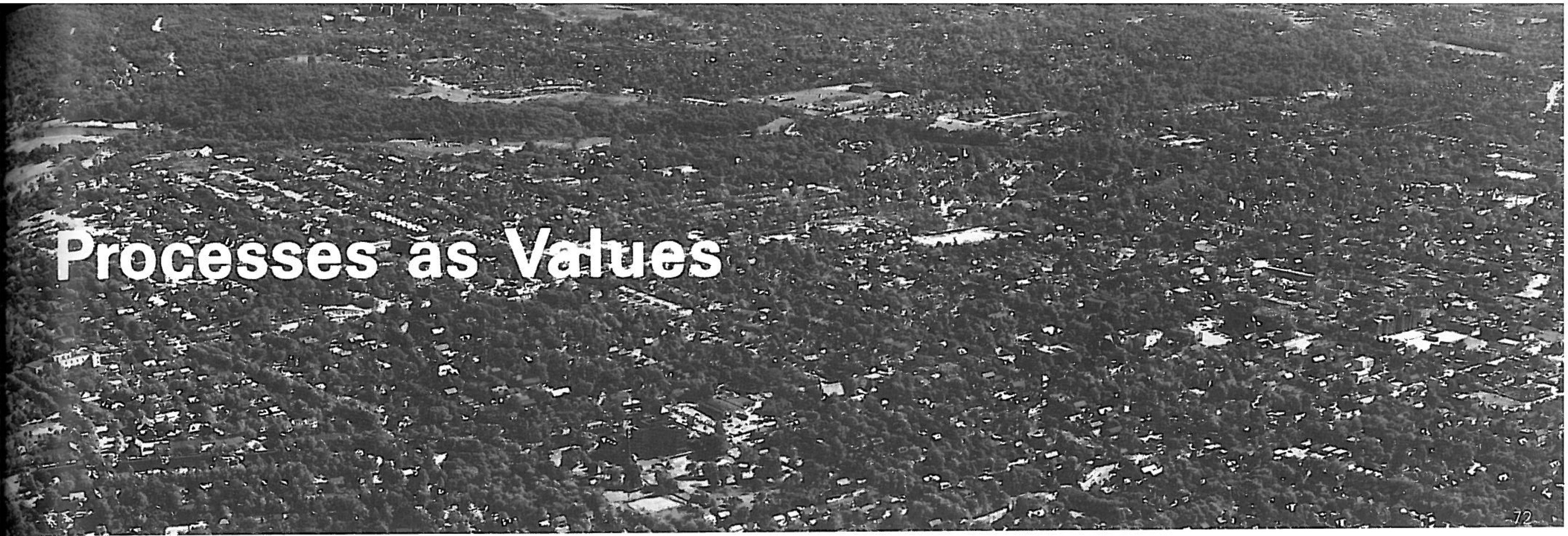
The problem lies not in absolute area but in distribution. We seek a concept that can provide an interfusion of open space and population. The low attributed value of open space ensures that it is transformed into urban use within the urban area and at the perimeter. Customary urbanization excludes interfusion and consumes peripheral open space.

Yet as the area of a circle grows with the square of the radius, large open-space increments can exist within the urban perimeter without major increase to the radius or to the time distance from city center to urban fringe.

This case study reveals the application of the ecological view to the problem of selecting open space in a metropolitan region. For the moment, it is enough to observe that this view could considerably enhance the present mode of planning, which disregards natural processes all but completely and which, in selecting open space, is motivated more by standards of acres per thousand for organized sweating than by a concern for the place and face of nature in the metropolis.

*Study on the Philadelphia airshed conducted under direction of the writer by Hideki Shimizu, Department of Landscape Architecture, University of Pennsylvania, 1963, unpublished.

This study was derived from Metropolitan Open Space from Natural Process, a research project supported by the Urban Renewal Administration, the States of Pennsylvania and New Jersey. The author was the principal investigator and the work published herein derives exclusively from his research. The initial project director was Dr. W. L. C. Wheaton. Subsequently this role was filled by Dr. David A. Wallace. Other investigators included Anne Louise Strong, Dr. William Grigsby, Dr. Anthony Tomazinas, Dr. Nohad Toulon and Mr. William H. Roberts. Research assistants, responsible for the mapping, were Mr. Donald Phimister and Mr. Frank Shaw.



Processes as Values

During a period when many values have depreciated, the celebrated 5-cent fare on the Staten Island ferry has long persisted. We can savor this as we proceed to the next case study—Staten Island, the Borough of Richmond. But let us see this area within its region, the hinterland of New York City. It is clear from even the most superficial examination that Manhattan and its surround offered a magnificent site for a city. Values are abundant, the crystalline rocks of Manhattan on or near the surface offer magnificent foundations, a splendid deep river and natural harbor, two bays at Jamaica and Newark, the noble Hudson draining a rich and beautiful hinterland, (the paradisiacal river of the Indians which flowed in both directions), the ocean and beaches, marshes and meadows, palisades, ridges and not least, a number of islands, among them Staten Island.

Given the powers of hindsight, it is clear that it would have been most advantageous if an evaluation of these resources had been made some hundreds of years ago and this had been incorporated into a plan. In such a setting a great termitary could be built upon Manhattan whose inhabitants could roam to ocean and river, beach and bay, marshes and meadow and to the many islands.

The ideal is seldom a choice of either/or, but rather the combination of both or all. One dreams of the museum and cabaret, concert hall and ball park within stone's throw, but it would be as splendid if the mountains, the ocean and the primeval forest were at the doorstep, the eagle perched on the penthouse. Save for the mountains, this could easily have been in Manhattan.

The daily trip from suburb to city and back is a retracing of history; the inward trip from country to city symbolizes the evolution from land-based life to the emergence of communities, and the return goes back through time to a hint of the earliest relation of man with the land. It is a deeply felt need and its most powerful testimony is the flight to the suburbs, the greatest population migration in history. The company of men, the power of institution, the competition, stimulus, diversity and opportunity that the city represents are of great value indeed, but the ancient memory insists upon a return to the land, as contrast, into the world of nonhuman creatures and things. This alternation is both necessary and good. We can think of the city as a great zoo to which the gregarious animals voluntarily make their daily way by familiar trails to enter their cages, rather like the starlings whose penchant for bridge trusses is uncomfortably similar. The instinct of the caged animal to return to the wild seems to persist in that most domesticated of all animals—man. The original setting of Manhattan offered great opportunities for this alternation between city and country, from the greatest concentration of man to the wildest of nature. If the analogy of city as zoo is offensive, does it make a difference if we reverse the figure and assume that the city is the habitat of civilized man and nature is the zoo? There could then be many zoos for terrestrial and aquatic creatures, in oceans and bays, rivers and marshes, forests and meadows—a wonderful choice of zoological gardens where the domesticated animals could visit the wild ones. But the question of who is behind the bars is not easy to resolve, as anyone knows who has watched a contemplative gorilla in a cage.

Whatever position we take it is clear that the hinterland of Manhattan offered the greatest range of environments that could be enjoyed by its inhabitants, and an evaluation would have shown this to be so. But it was not to be, and inexorable growth spread a smear of low-grade urban tissue expunging this great richness and value.

Had our hindsight been applied, Staten Island would have ranked high among the splendid resources for the city population. It is a special place—its geological history has made it so. Silurian schists form the spine of the island, but the great Wisconsin glacier of

Pleistocene time left its mark, for there lies the evidence of the terminal moraine. There are glacial lakes, ocean beaches, rivers, marshes, forests, old sand dunes and even satellite islands. Among its treasures were beds of oysters and clams so extensive that the earliest inhabitants could not conceive that they could ever be consumed. Nor were they—like many other resources, they were rendered useless by pollution. Staten Island retained its quality as a bucolic haven rather longer than any other area as near to Manhattan, but in the postwar period the speculative builders made it the testimony to their shortsightedness and greed. Yet, all is not lost; even though the Verazzano Bridge has opened the floodgates to urban development, some splendid residues still remain—the Greenbelt and much of the southern part of the island. Happily too, much of this land is owned by the City of New York and is administered by the Department of Parks. This client asked that a study be made of the island to discern its intrinsic suitabilities from which conclusions would be made upon the use and disposition of the land.

This is then a problem of evaluation: which lands are intrinsically suitable for conservation, for active and for passive recreation, which are most suitable for commerce and industry, and which for residential land use?

Staten Island was and remains a unique resource in New York City, but its value is fast disappearing. The last assault, precipitated by the Verazzano Bridge, could well lead to its demise. Hope for this island refuge lies almost entirely in the fact that the City of New York owns most of the remaining vacant land. It thus falls within the power of the City to determine the destiny of the Borough of Richmond.

What should be the destiny of this land? It could be voraciously consumed by the market for housing. In so doing, the last of the public values for New Yorkers which Staten Island represents will join the oblivion of other New York environs. Can it be otherwise? This study was an attempt to reveal the alternatives for the future destiny of the beleaguered island.

The basic proposition employed is that any place is the sum of historical, physical and biological processes, that these are dynamic, that they constitute social values, that each area has an intrinsic suitability for certain land uses and finally, that certain areas lend themselves to multiple coexisting land uses.

The serpentine ridge and the diabase dyke of Staten Island can only be comprehended in terms of historical geology. The superficial expression of the island is a consequence of Pleistocene glaciation. The climatic processes over time have modified the geological formations, which account for current physiography, drainage and distribution of soils. Various associations of plant species occupy the place, making it possible for a myriad of animal species to exist. Human occupation modifies the natural processes by its own contribution.

The island has come to be as a result of the dynamism that is inherent in all natural process. It is a mute record of mountain building, submergence into ancient, long-extinct seas and lava flows. Ice sheets have advanced over it and retreated. But cycles of seasons and tides, the hydrological cycle and the recycling of vital nutrients are still going on. Hills are eroded and the sediments follow gravitational paths. Dunes form and create bays that fill over time. Hurricanes sweep up over the oceans and bring tidal inundation. It is important to recognize the dynamism of physical and biological processes and, more important, to recognize that these affect man and are affected by his intervention.

Land, air and water resources are indispensable to life and thus constitute social values. The bayshores have a high value for recreational and residential development but also represent a negative value because of their susceptibility to tidal inundation. The surface waters are a resource for water supply, recreation and disposal of effluents, but their positive value is easily abused by pollution. Water management, prevention of erosion, provision of habitat for wildlife and a retreat for study and delight are several of the social values represented by forest land and then lost when a forest is allowed to succumb to advancing development.

A recognition of these social values, inherent in natural processes, must precede prescription for the utilization of natural resources.

Once it has been accepted that the place is a sum of natural processes and that these processes constitute social values, inferences can be drawn regarding utilization to ensure optimum use and enhancement of social values. This is its intrinsic suitability. For example, flat land with good surface and soil drainage is intrinsically the most suitable land for intensive recreation, while areas of diverse topography represent a higher value for passive recreation.

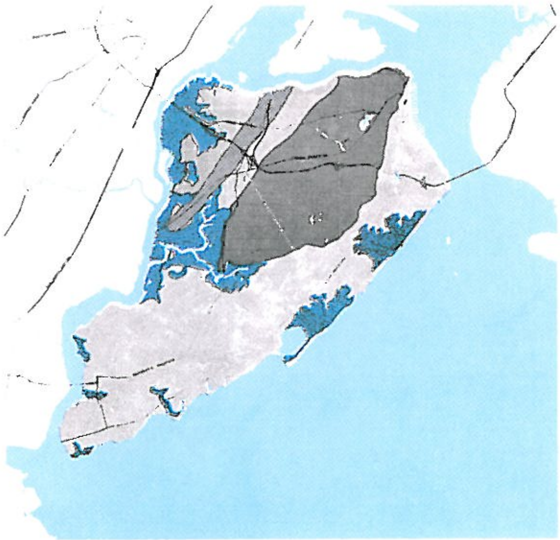
The social values represented by the natural processes more often than not are inherently suitable for a multiplicity of human uses. Flat well-drained land is as suitable for intensive recreation as it is for commercial-industrial development. Areas of diversity and high scenic interest have a high social value for conservation and passive recreation, at the same time being highly desirable locations for residential development. These apparent conflicts can be resolved in a number of ways. Because of their scarcity and vulnerability, certain resources may represent such high value for conservation that other uses should be excluded. Multiple uses of some areas may be permitted if it is assured that intrinsic values are not compromised. Yet in other cases where two uses are coequally suitable, it remains with society to make the choice.

The proposition has been employed and in the following pages can be seen each of the intrinsic suitabilities and the resulting

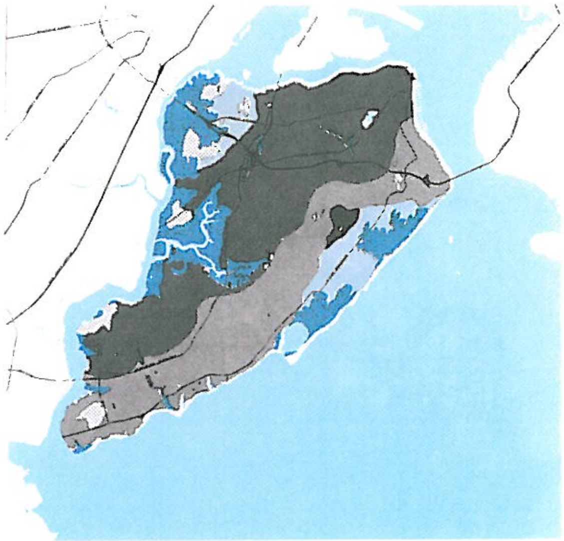
synthesis. We can review it now. The first point to be made is that it is not a plan. A plan includes the entire question of demand and the resolution of demand relative to supply, incorporating the capacity of the society or institution to realize its objectives. The Staten Island Study merely indicates those areas where certain land uses, both single and multiple, can occur with the least costs and the greatest savings and benefits. In order to make a plan, it is necessary to calculate demand for the constituent land uses and the locational and formal requirement of these, and to recognize the instruments available to society in both the public and private domain. The study awaits this information for completion.

But even at this stage it has innovative virtues that justify examination. The first of these is that it employs rational method: the evidence is derived, in the main, from exact sciences. The statements made on the major data subjects—geology, hydrology, soils, plant ecology and wildlife—are collected from substantial sources and are unlikely to contain major errors. This holds true for the interpretations of zones of atmospheric pollution, tidal inundation, rocks in terms of compressive strength, soil drainage and the rest.

In addition to being rational, the method is explicit. Any other person, accepting the method and the evidence, is likely to reach the same conclusions as those demonstrated in the study. This is in direct contrast to the bulk of planning, where the criteria are often obscure and covert. Moreover, this method permits a most important improvement in planning method—that is, that the community can employ its own value system. Those areas, places, buildings or spaces that it cherishes can be so identified and incorporated into the value system of the method. Today many planning processes, notably highway planning, are unable to incorporate the value system of the community to be transected. At best, the planner supplies his own distant judgment.

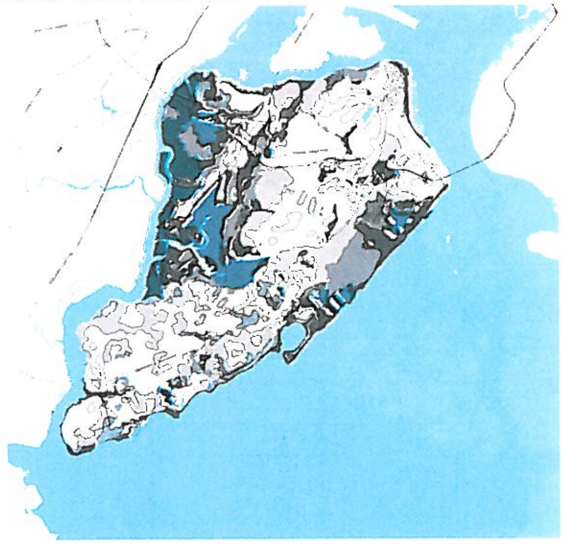


BEDROCK GEOLOGY



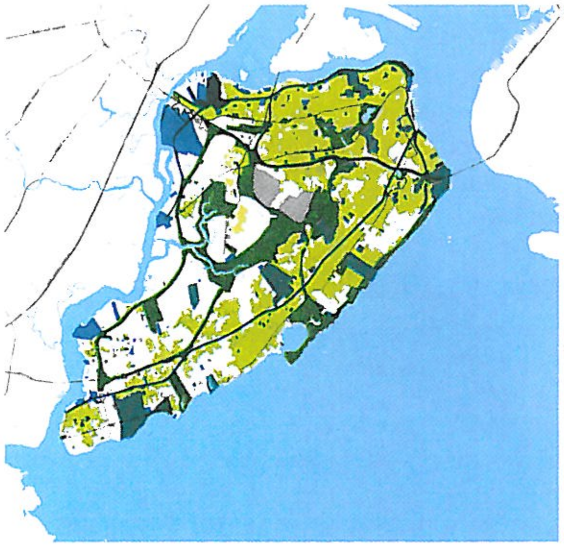
SURFICIAL GEOLOGY

HYDROLOGY

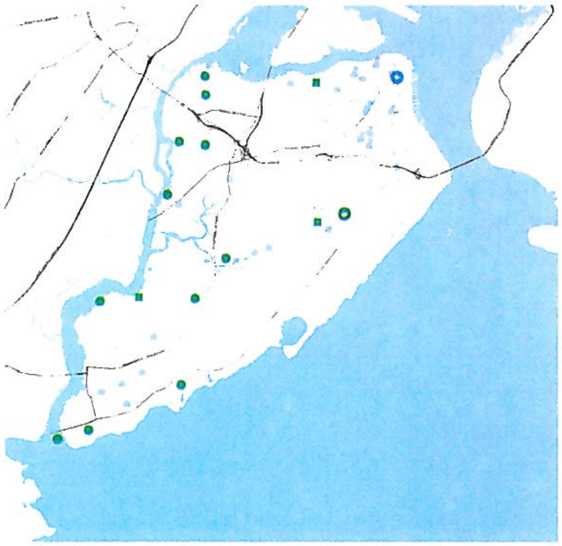


SOIL DRAINAGE ENVIRONMENTS

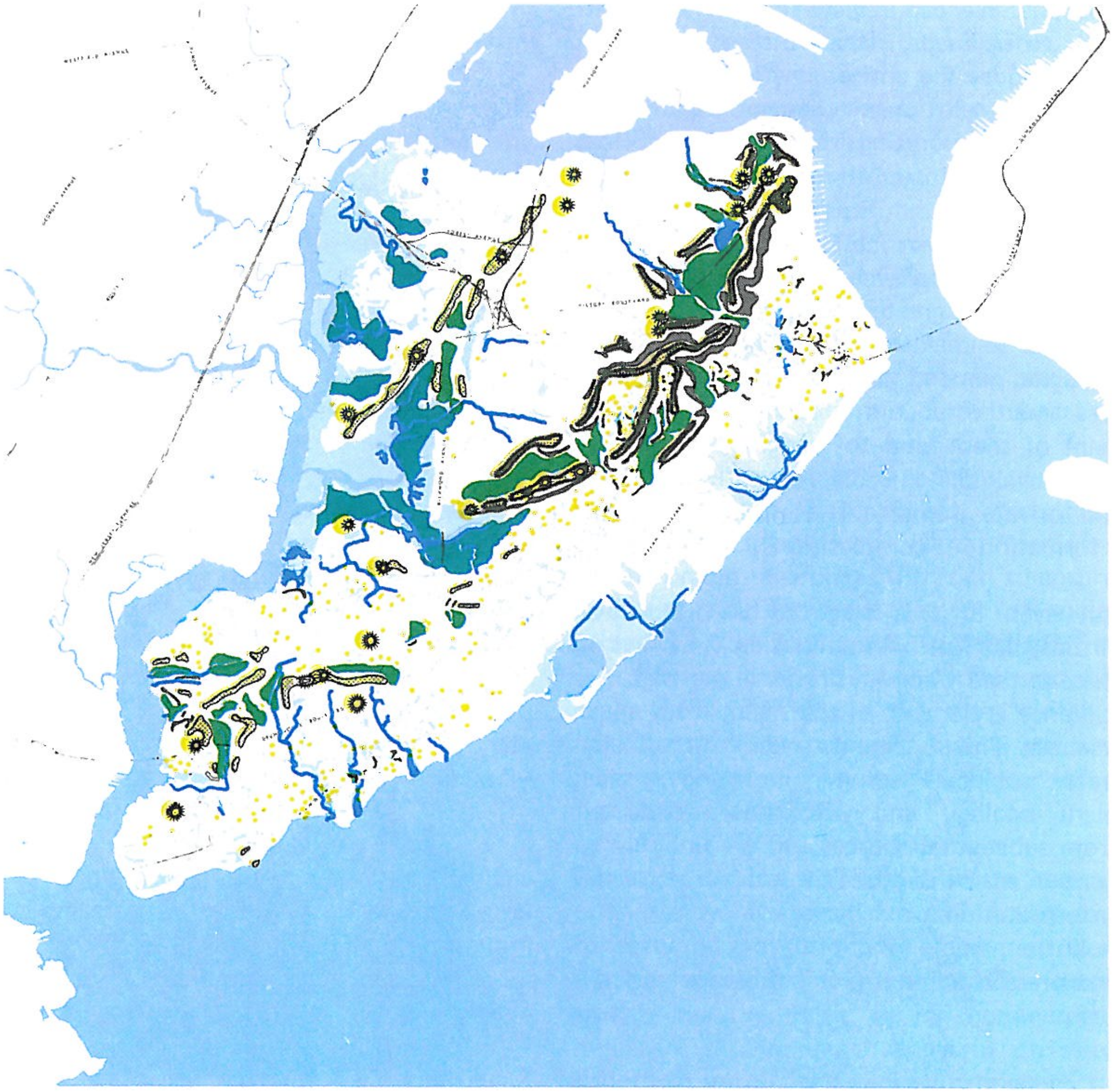
How does one proceed with this task? Well, we will begin with the original proposition, for it has served us well: nature is process and value, exhibiting both opportunities and limitations to human use. Therefore, we must identify the major physical and biological processes that caused Staten Island to be and that operate there now. We will not, in this case study, describe the content of the data. Many of these will be illustrated but the exposition will be limited to a description of the method alone. The previous studies have been much simpler than this problem—survival by the sea, a highway alignment and the place of nature in the metropolis. In this instance we are required to identify the entire area for its intrinsic suitability for all prospective land uses. As in the highway problem, all basic data were compiled and mapped—climate, historical geology, surficial geology, physiography, hydrology, soils, plant ecology, wildlife habitats and land use. These data are of little use until they are interpreted and evaluated. For instance, general data on climate are of little significance, but those on hurricanes and the resultant inundation are vital, for with them we can identify gradients of susceptibility to inundation. The basic data are thus interpreted and reconstituted within a value system. In the earlier highway study it was observed that interstate highways generally



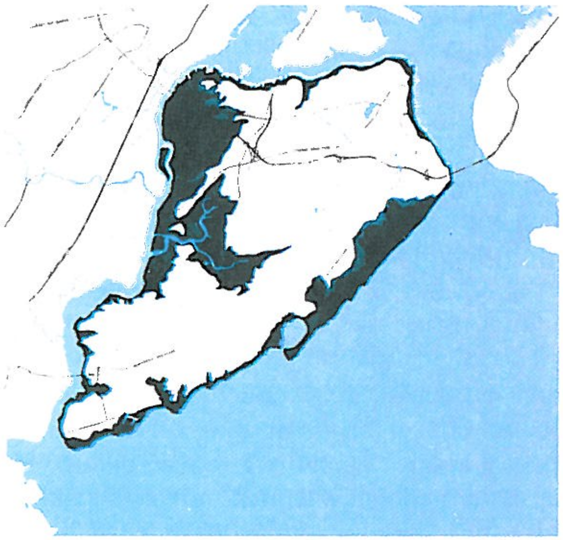
EXISTING LAND USE



HISTORICAL LANDMARKS

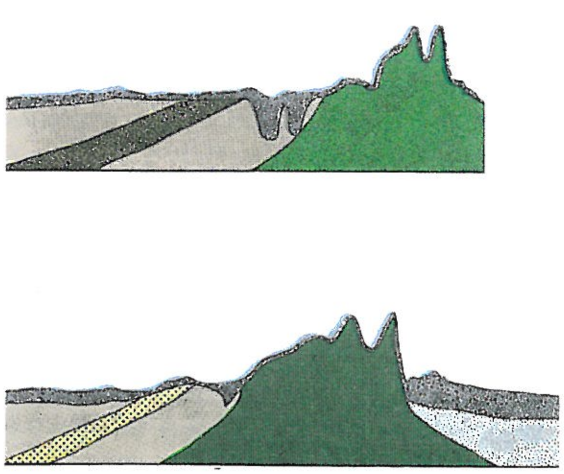


PHYSIOGRAPHIC FEATURES



TIDAL INUNDATION

GEOLOGIC FEATURES

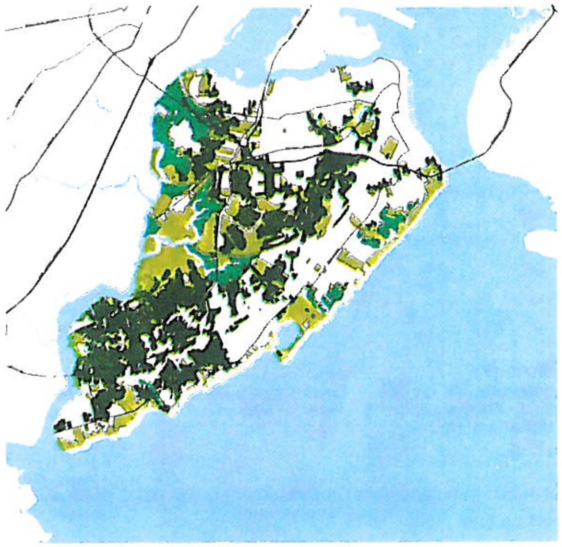


GEOLOGIC SECTIONS

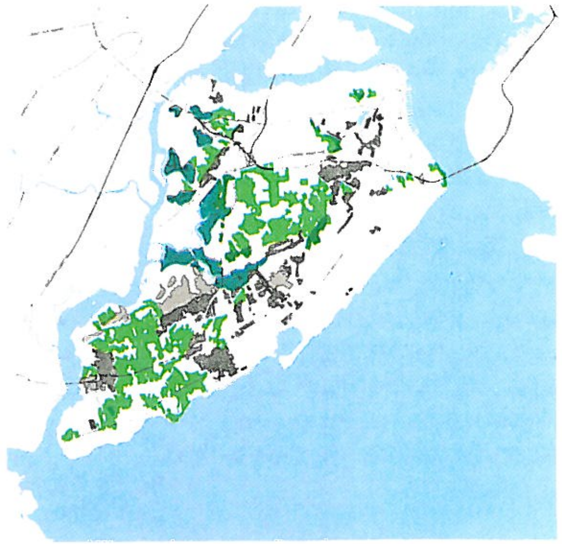
do not exceed a three per cent slope. Thus any existing slopes in excess of this constitute a penalty; slopes of three per cent or less are a saving. Further, it costs more to excavate rock than it does sand or gravel. Moreover, the presence of these latter materials may well be a saving, as they can be utilized in highway construction.

From each of the major data categories a number of factors are selected and evaluated. From geology we identify features of geologic, scientific and educational value and grade them from unique to abundant; rocks are evaluated for their compressive strength and ranked as foundation conditions, and so on, for every category. For certain land uses the maximum condition will be preferable, for others it will be the minimum that has the highest value. The least tidal inundation is to be preferred, but the highest scenic quality is the greatest value.

For each prospective land use there will be certain factors of greatest importance and these can be selected. Moreover, there will be a ranking of importance and so the factors can be arranged in a hierarchy. In addition, in certain cases some factors will be conducive to specific land uses while others are restrictive. In the selection of areas intrinsically suitable for conservation, the factors selected were: features of historic



EXISTING VEGETATION

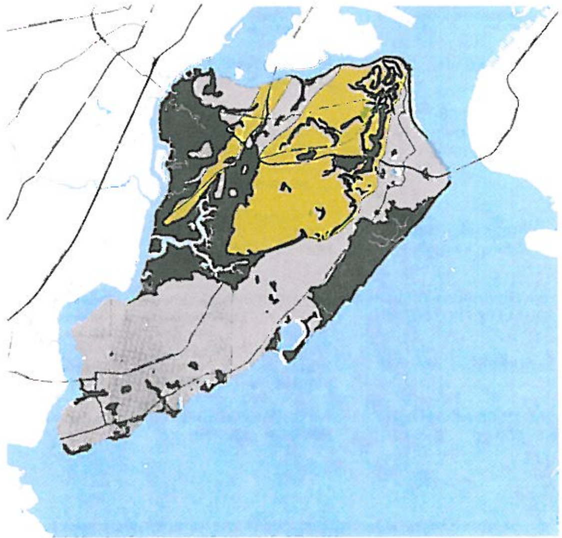


FOREST:ECOLOGICAL ASSOCIATIONS

EXISTING WILDLIFE HABITATS

FOREST:EXISTING QUALITY

SLOPE



SOIL LIMITATIONS:FOUNDATION

SOIL LIMITATIONS:WATER-TABLE

value, high quality forests and marshes, bay beaches, streams, water-associated wildlife habitats, intertidal wildlife habitats, unique geological and physiographic features, scenic land and water features and scarce ecological associations. As an example of conducive and restrictive factors, selection of the most suitable areas for residential land use would include attractive surroundings, and so scenic land features, locations near water and the presence of historic sites and buildings will be positive factors, while excessive slopes, poor drainage and susceptibility to flooding will be negative factors.

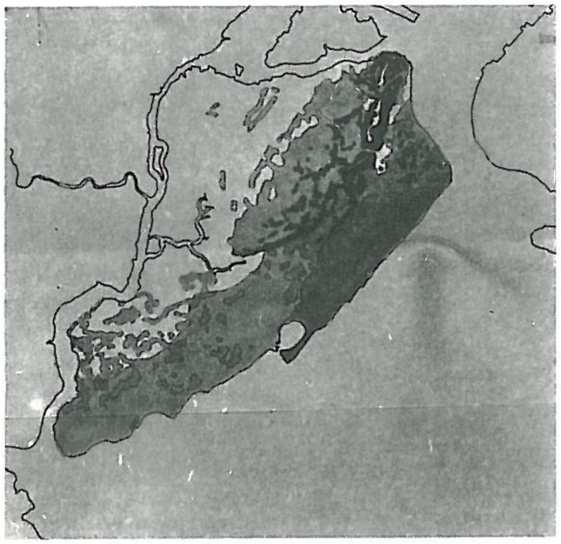
The application of this concept can be seen in the adjacent charts. Over thirty factors were considered. Those considered were subdivided in the categories of climate, geology, physiography, hydrology, soils, vegetation, wildlife habitats and land use. Within each of these categories data were collected on factors of importance to all prospective land use. From the original sources—climate, geology, etc., the factors of greatest importance were selected. In the general subject of climate the matter of air pollution was deemed important as was tidal inundation from hurricanes. Within the category of geology features of unique scientific value were identified and the major surface rock types were classed for compressive strength. Following the identification of the most important factors, each one was evaluated in a gradient of five values. For instance, serpentine and diabase constitute class one foundation conditions while marsh and swamp occupy the lowest rank on the scale. All factors were so evaluated. The relevance of the factors considered to specific land uses was next indicated. Further, the direction of the value system was shown. A blue dot indicates rank order from left to right. A black dot indicates the reverse order. Moreover the importance of the factor must also be evaluated. Factors of highest importance are shown with full black and blue dots; lower values decrease in color and tonal intensity.

ECOLOGICAL FACTOR	RANKING CRITERIA	PHENOMENA RANK I	II	III	IV	V	VALUE FOR LAND USE C	P	A	R	I
CLIMATE											
AIR POLLUTION	INCIDENCE MAX ► MIN	High	Medium	Low		Lowest		●	●	●	
TIDAL INUNDATION	INCIDENCE MAX ► MIN	Highest Recorded	Highest Projected			Above Flood-Line			●	●	●
GEOLOGY											
FEATURES OF UNIQUE, SCIENTIFIC AND EDUCATIONAL VALUE	SCARCITY MAX ► MIN	1 Ancient Lakebeds 2 Drainage Outlets	1 Terminal Moraine 2 Limit of Glaciation 3 Boulder Trail	Serpentine Hill	Palisades Outlier	1 Beach 2 Buried Valleys 3 Clay Pits 4 Gravel Pits	●	●		●	
FOUNDATION CONDITIONS	COMPRESSIVE STRENGTH MAX ► MIN	1 Serpentine 2 Diabase	Shale	Cretaceous Sediments	Filled Marsh	Marsh and Swamp			●	●	●
PHYSIOGRAPHY											
FEATURES OF UNIQUE, SCIENTIFIC AND EDUCATIONAL VALUE	SCARCITY MAX ► MIN	Hummocks and kettleholes within the Terminal Moraine	Palisades Outlier	Moraine Scarps and lakes along the Bay Shore	Breaks in Serpentine Ridge		●	●			
LAND FEATURES OF SCENIC VALUE	DISTINCTIVE MOST ► LEAST	Serpentine Ridge and Promontories	Beach	1 Escarpments 2 Enclosed Valleys	1 Berms 2 Promontories 3 Hummocks	Undifferentiated	●	●	●	●	
WATER FEATURES OF SCENIC VALUE	DISTINCTIVE MOST ► LEAST	Bay	Lake	1 Pond 2 Streams	Marsh	1 The Narrows 2 Kill Van Kull 3 Arthur Kill	●	●	●		
RIPARIAN LANDS OF WATER FEATURES	VULNERABILITY MOST ► LEAST	Marsh	1 Stream 2 Ponds	Lake	Bay	1 The Narrows 2 Kill Van Kull 3 Arthur Kill	●		●	●	●
BEACHES ALONG THE BAY	VULNERABILITY MOST ► LEAST	Moraine Scarps	Coves	Sand Beach			●	●	●	●	
SURFACE DRAINAGE	PROPORTION OF SURFACE WATER TO LAND AREA MOST ► LEAST	Marsh and swamp	Areas of constricted drainage	Dense stream/swale network	Intermediate stream/swale network	Sparse stream/swale network	●	●	●	●	●
SLOPE	GRADIENT HIGH ► LOW	Over 25%	25–10%	10–5%	5–2½%	2½–0%			●	●	●
HYDROLOGY											
MARINE											
Commercial Craft	NAVIGABLE CHANNELS DEEPEST ► SHALLOWEST	The Narrows	Kill Van Kull	Arthur Kill	Fresh Kill	Raritan Bay		●			●
Pleasure Craft	FREE EXPANSE OF WATER LARGEST ► SMALLEST	Raritan Bay	Fresh Kill	The Narrows	Arthur Kill	Kill Van Kull	●	●	●		
FRESH WATER											
Active recreation (swimming, paddling, model-boat sailing, etc.)	EXPANSE OF WATER LARGEST ► SMALLEST	Silver Lake	1 Clove Lake 2 Grassmere Lake 3 Ohrbach Lake 4 Arbutus Lake 5 Wolfes Pond	Other ponds	Streams		●	●	●		
Stream-side recreation (fishing, trails, etc.)	SCENIC MOST ► LEAST	Nonurbanized perennial streams	Nonurbanized intermittent streams	Semiurbanized streams	Urbanized streams		●	●			
WATERSHEDS FOR STREAM QUALITY PROTECTION	SCENIC STREAMS MOST ► LEAST	Nonurbanized perennial streams	Nonurbanized intermittent streams	Semiurbanized streams	Urbanized streams		●	●	●	●	
AQUIFERS	YIELD HIGHEST ► LOWEST	Buried valleys		Cretaceous Sediments		Crystalline rocks	●				●
AQUIFER RECHARGE ZONES	IMPORTANT AQUIFERS MOST ► LEAST	Buried valleys		Cretaceous Sediments		Crystalline rocks	●				

C CONSERVATION, P PASSIVE RECREATION, A ACTIVE RECREATION, R RESIDENTIAL DEVELOPMENT, I COMMERCIAL & INDUSTRIAL DEVELOPMENT

ECOLOGICAL FACTOR	RANKING CRITERIA	PHENOMENA RANK I	II	III	IV	V	VALUE FOR LAND USE C	P	A	R	I
PEDOLOGY											
SOIL DRAINAGE	PERMEABILITY AS INDICATED BY THE HEIGHT OF WATER TABLE MOST ► LEAST	Excellent-good	Good-fair	Fair-poor	Poor	Nil	●		●	●	●
FOUNDATION CONDITIONS	COMPRESSIVE STRENGTH AND STABILITY MOST ► LEAST	Gravelly to stony, sandy loams	Gravelly sand or silt loams	Gravelly sandy to fine sandy loam	1 Sandy loam 2 Gravel 3 Beach sands	1 Alluvium 2 Swamp Muck 3 Tidal marshlands 4 Made land			●	●	●
EROSION	SUSCEPTIBILITY MOST ► LEAST	Steep slopes over 10%	Any slope on gravelly sandy to fine sandy loam	Moderate slopes (2½-10%) on 1 Gravelly sand or silt loams 2 Gravelly to stony sandy loams	Slopes (0-2½%) on gravelly sand or silt loams	Other soils	●		●	●	●
VEGETATION											
EXISTING FOREST	QUALITY BEST ► POOREST	Excellent	Good	Poor	Disturbed	None	●	●	●	●	●
FOREST TYPE	SCARCITY MOST ► LEAST	1 Lowland 2 Upland dry	Marsh	Upland	Upland moist	Absence	●	●		●	
EXISTING MARSHES	QUALITY BEST ► POOREST	Good	Fair		Poor (filled)	None	●	●	●	●	●
WILDLIFE											
EXISTING HABITATS	SCARCITY MOST ► LEAST	Intertidal	Water-related	Field and forest	Urban	Marine	●	●	●		
INTERTIDAL SPECIES	ENVIRONMENTAL QUALITY BASED ON INTENSITY OF SHORE ACTIVITY	1	2	3	4	5					
	LEAST ACTIVITY ► MOST ACTIVITY	1	2	3	4	5	●	●	●		
WATER-ASSOCIATED SPECIES	ENVIRONMENTAL QUALITY BASED ON THE DEGREE OF URBANIZATION	1	2	3	4	5					
	NON URBANIZED ► FULLY URBANIZED	1	2	3	4	5	●	●	●	●	
FIELD AND FOREST SPECIES	FOREST QUALITY BEST ► POOREST	1	2		3		●	●	●	●	
URBAN-RELATED SPECIES	PRESENCE OF TREES ABUNDANT ► ABSENT	1		2		3		●			
LAND USE											
FEATURES OF UNIQUE, EDUCATIONAL, AND HISTORICAL VALUE	IMPORTANCE MOST ► LEAST	Richmond Town	1 Amboy Road 2 Tottenville Conference	Area with abundance of landmarks	Area with sparseness of landmarks	Area with absence of landmarks	●	●		●	
FEATURES OF SCENIC VALUE	DISTINCTIVE MOST ► LEAST	The Verazzano Bridge	Ocean Liner Channel	Manhattan Ferry	1 The Goethals Bridge 2 The Outer-bridge crossing 3 The Bayonne Bridge	Absence	●	●	●	●	●
EXISTING AND POTENTIAL RECREATION RESOURCES	AVAILABILITY MOST ► LEAST	1 Existing public open space 2 Existing Institutions	Potential nonurbanized recreation areas	Potential urbanized recreation areas	Vacant land (with low recreation potential)	Urbanized areas	●	●	●	●	

C:CONSERVATION; P:PASSIVE RECREATION; A:ACTIVE RECREATION; R:RESIDENTIAL DEVELOPMENT; I:COMMERCIAL & INDUSTRIAL DEVELOPMENT



SOILS; MOST-LEAST EROSION

SOILS; LEAST-MOST EROSION

Each factor was mapped in tones of gray from most to least, and this same information was reversed to be employed in inverted order when necessary. All of the maps were made as transparencies. The group of relevant factors for each prospective land use was assembled and photographed. The results were then value gradients that incorporated all the appropriate factors. These maps showed the maximum concurrence of all the positive factors and the least restrictions. Processes, reconstituted as values, indicated the areas intrinsically suitable for each of the land uses considered—recreation, conservation and both the residential and industrial-commercial aspects of urbanization.

As an example of the application of the method, the constituent values employed to reveal areas most suitable for conservation are illustrated. The salient factors selected for this search included:

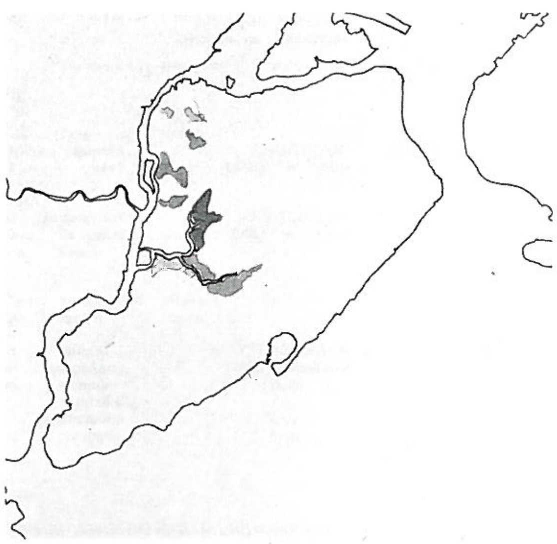
features of historic value
high-quality forests
high-quality marshes
bay beaches
streams
water-associated wildlife habitats
intertidal wildlife habitats
unique geological features
unique physiographic features
scenic land features
scenic water features
scarce ecological associations

Each of the constituent maps is an evaluation within the appropriate category, represented in five divisions, with the darkest tone representing the highest value and the lowest value shown as blank. All twelve maps were made into transparent negatives, which were superimposed and photographed. The resulting photograph represented the summation of all of the values employed and was therefore indicative of the areas most to least intrinsically suitable for conservation. This photograph was reconstituted into a single map, with the values for conservation indicated in five values. Thus the darker the tone the greater the intrinsic suitability for conservation.

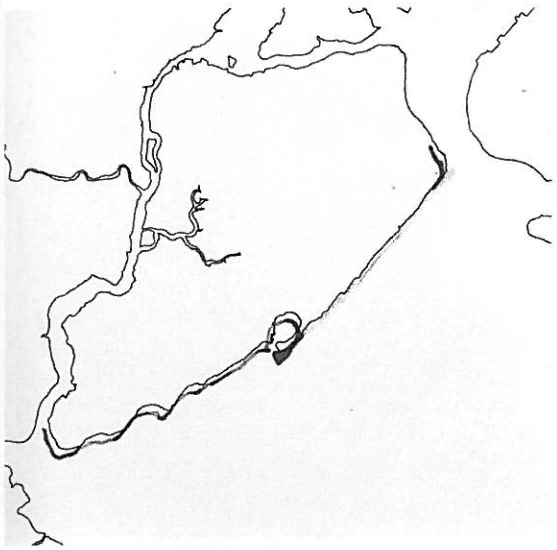
CONSERVATION AREAS

HISTORIC FEATURES VALUE

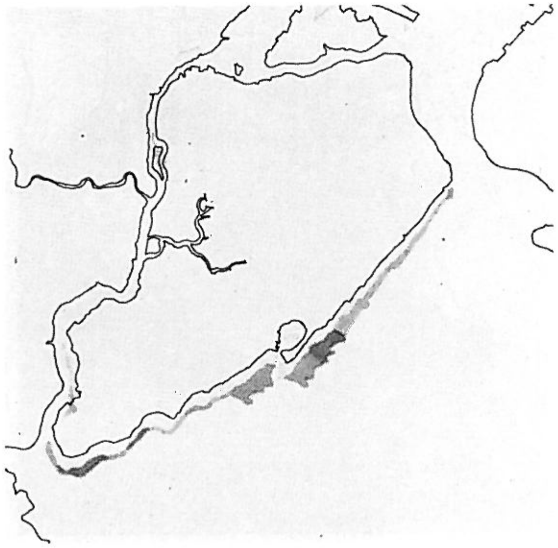
EXISTING FOREST QUALITY



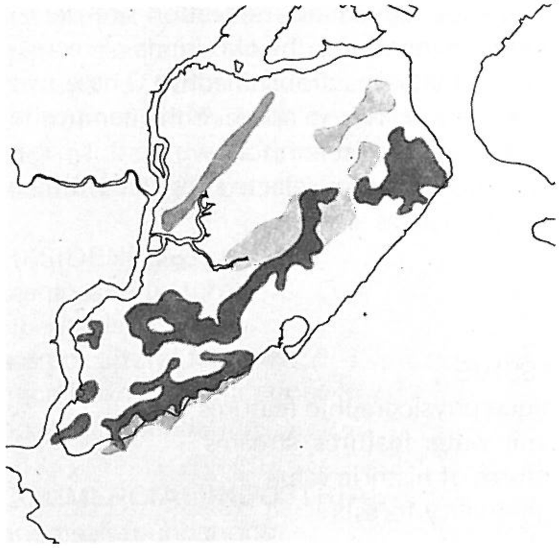
MARSH QUALITY



BEACH QUALITY

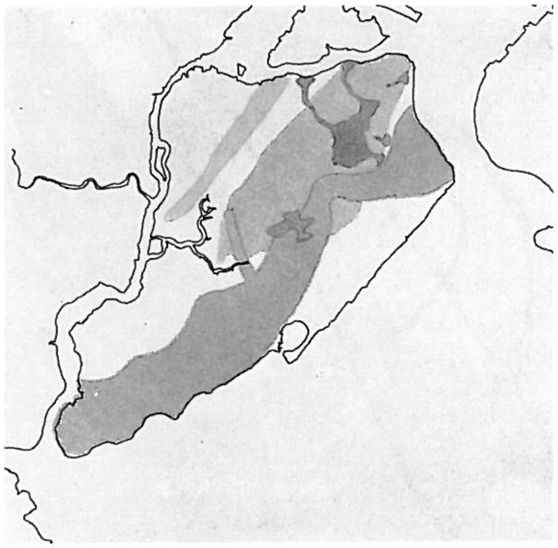


INTERTIDAL HABITAT VALUE



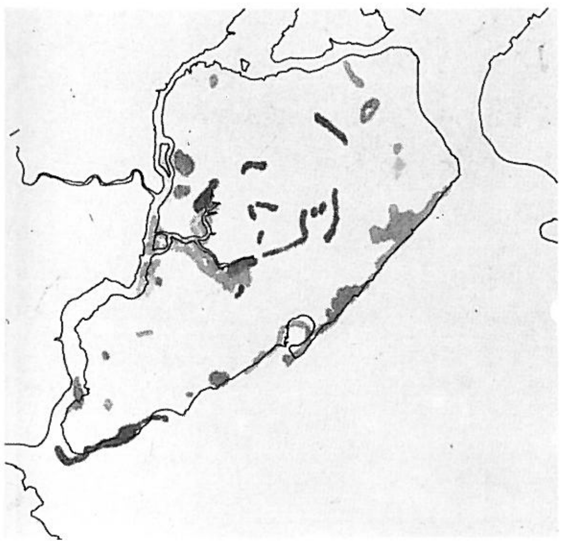
SCENIC VALUE (LAND)

STREAM QUALITY

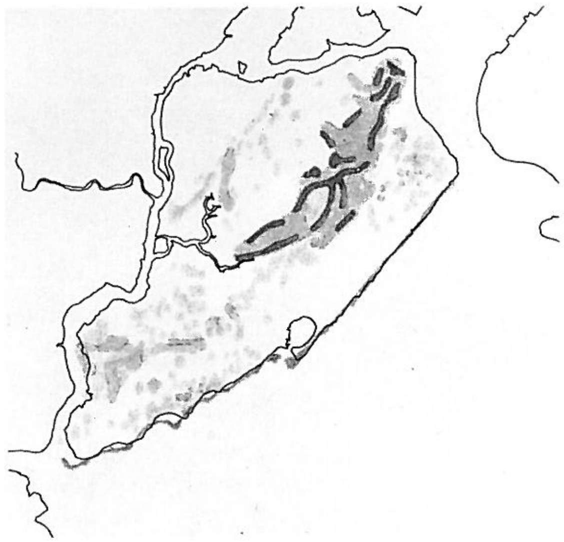


GEOLOGIC FEATURES VALUE

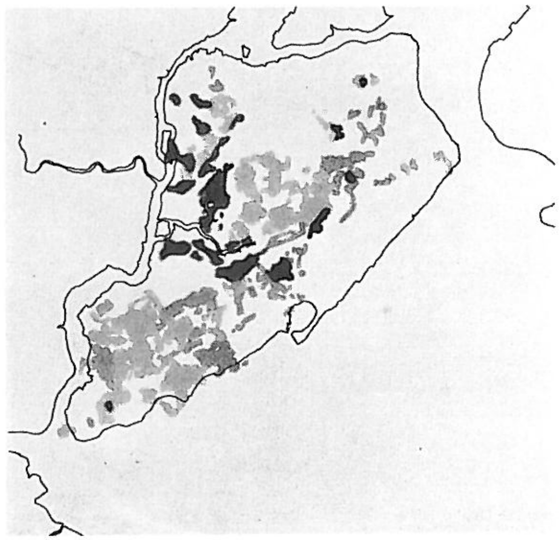
SCENIC VALUE (WATER)



WATER WILDLIFE VALUE



PHYSIOGRAPHIC FEATURES VALUE



ECOLOGICAL ASSOCIATIONS VALUE

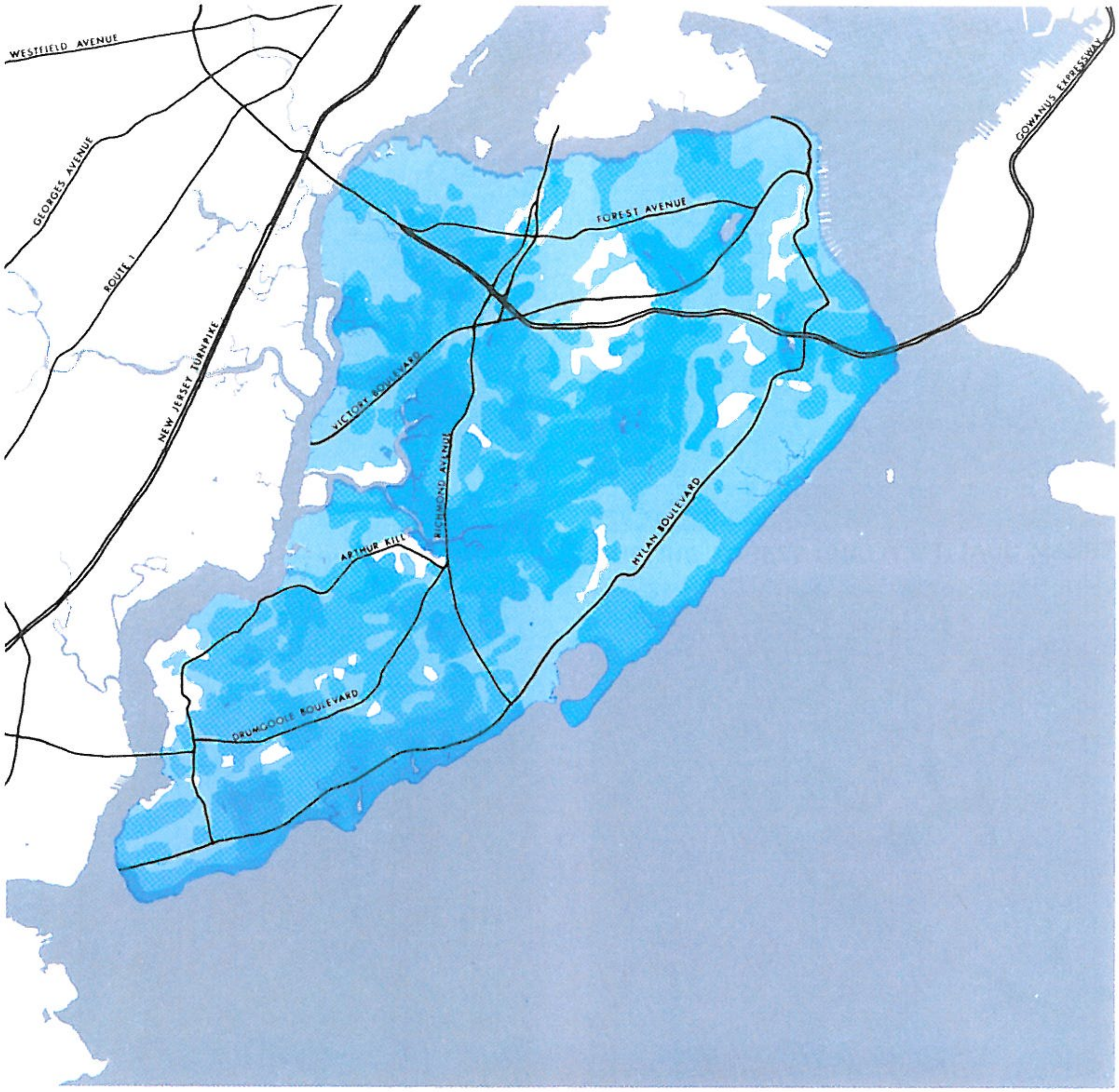
Areas most suited for recreation are determined separately for the two kinds of recreational activity—passive and active. These two are then combined to arrive at the composite suitability for recreation shown on this page. The salient factors selected for determining recreation areas are:

PASSIVE
unique physiographic features
scenic water features, streams
features of historic value
high-quality forests
high-quality marshes
scenic land features
scenic cultural features
unique geologic features
scarce ecological associations
water-associated wildlife habitats
field and forest wildlife habitats

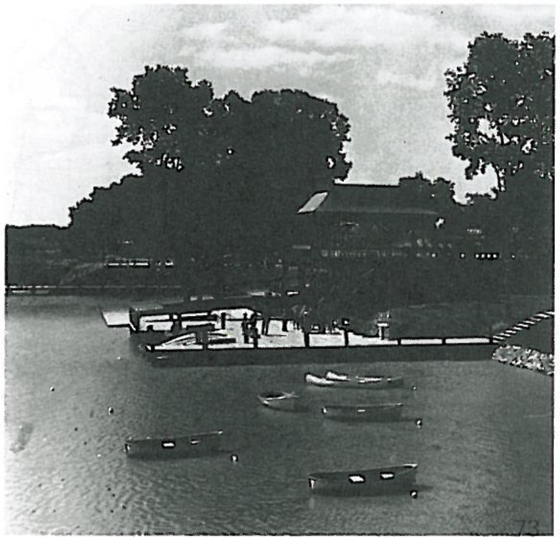
ACTIVE
bay beaches
expanse of water for pleasure craft
fresh water areas
riparian lands
flat land
existing and potential recreation areas


ACTIVE RECREATION SUITABILITY


PASSIVE RECREATION SUITABILITY



RECREATION AREAS


Landscape Architects: COPE, LINDER AND WALMSLEY

RESIDENTIAL SUITABILITY

UNSUITABILITY FOR URBANIZATION

URBANIZATION AREAS

Areas most suited for urbanization are determined separately for the two major components of urbanization: residential and commercial-industrial developments. For each of these the most permissive factors are identified. These are:

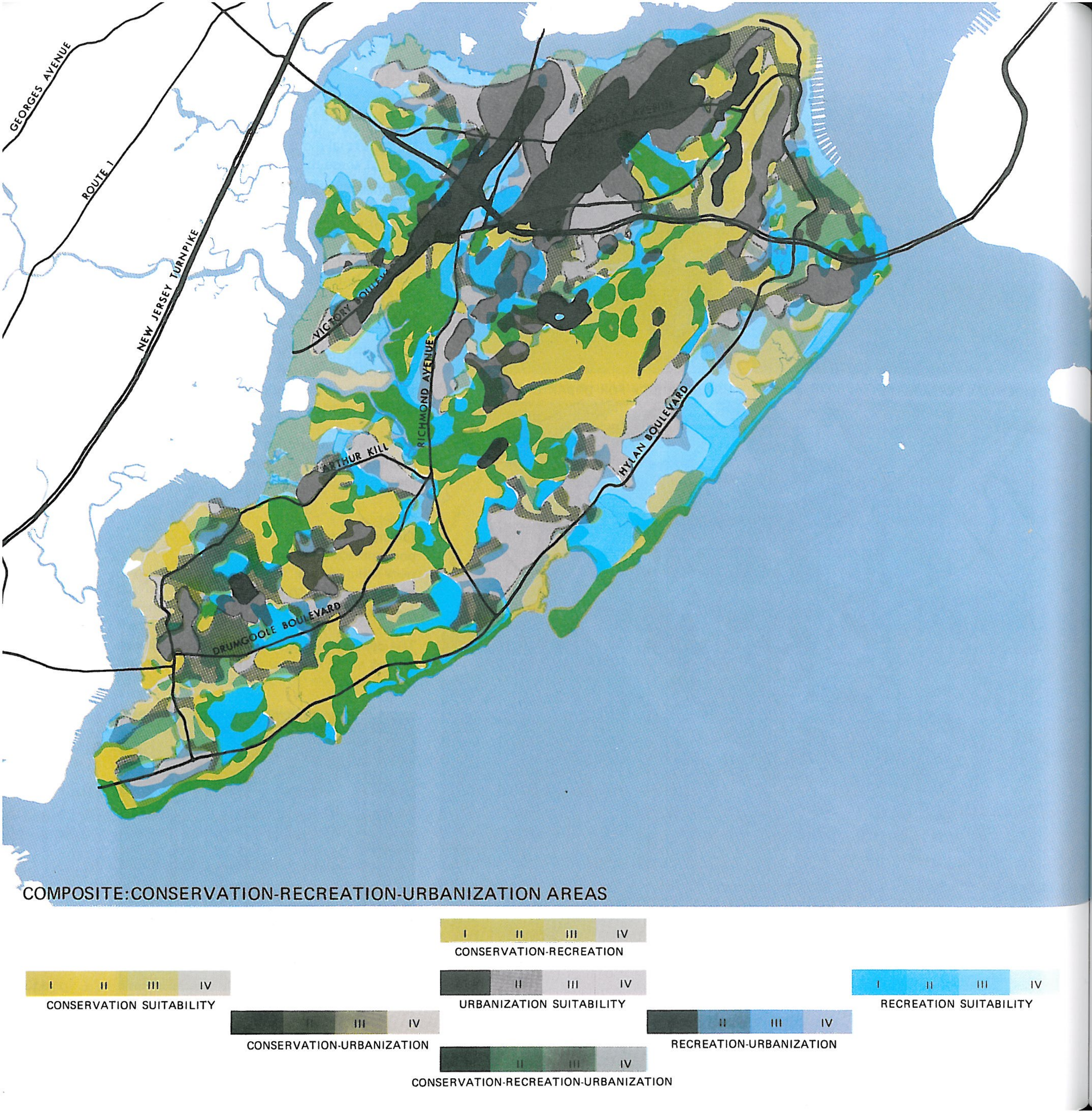
RESIDENTIAL
scenic land features
riparian lands
scenic cultural features
good bedrock foundations
good soil foundations

COMMERCIAL-INDUSTRIAL
good soil foundations
good bedrock foundations
navigable channels

The most restrictive factors which are common to these developments are also identified:

slopes
forested areas
poor surface drainage
poor soil drainage
areas susceptible to erosion
areas subject to flooding

The composite suitability for urbanization is arrived at by combining these and is shown on this page.



COMPOSITE: CONSERVATION-RECREATION-URBANIZATION AREAS

There are now maps of intrinsic suitability for residential land use, commerce-industry, conservation, passive and active recreation. These have an existence in their own right, but we seek to find not only intrinsic single uses, but also compatible coexisting ones and areas of competition. We can then take complementary pairs and reduce them to single maps. Commerce-industry and residential use can be incorporated into a single map of urban suitability. Active and passive recreation can be combined into a single one of recreational suitability. We then have a residuum of three maps—Conservation, Recreation and Urbanization—which we are required to resolve. While the single suitabilities could be represented using tones of gray on transparent maps, this technique cannot avail us now. It is necessary to employ color. Let us allocate yellow to conservation and reconstitute the tones of gray into a range of brightness. We will map recreation in grades of blue and urbanization in gray. Where a land use has no conflict, nor is it complementary, we can map the area in its appropriate color and in a scale of brightness appropriate to its value. Where there are complementarities, such as recreation and conservation, the combination of blue and yellow will produce green and the brightness will reflect the degree of value. The combination of gray and blue—urbanization and recreation—will show in the blue-gray range while a coequal suitability for all three categories will result in the combination of gray, blue and yellow producing a range of gray-greens. In the preparation of the final map it is impossible to resolve the suitabilities, compatibilities and conflicts by superimposition and photography and so the preemptive method was used. This consisted of locating all primary suitabilities not in competition with any other primary values and mapping them, thus preempting the appropriate areas. This is continued with secondary and tertiary values until the summary map shows all unitary, complementary and competing intrinsic land uses. Those shown as coequally suitable for more than one use may either compete or coexist.

By abandoning absolute economic values that cover only a small range of price values, and employing a relative system of most to least, it is possible to include all of the important factors that defy pricing by economists. While this denies an illusory precision of cost-benefit economics, it does show the relative concurrence of positive factors and their relative absence. Although we are unable to fix precise money values on these, it is safe to assume that, in the absence of any supervening value, the concurrence of the majority of positive factors in any one location does indicate its intrinsic suitability for the land use in question.

Another value is that the information so compiled and interpreted constitutes the base data required to subject any planning proposal to the test of least cost-maximum benefit. The values of the area in question for the major land uses have been identified, and the degree to which any proposal will destroy or enhance these can be demonstrated. Moreover, these same data simplify the quest for least-social-cost locations. By making explicit the factors employed, it is possible for society at large and for individuals to insist that the development process, both public and private, respond to these values. It would serve a most useful purpose if maps of the value of an area, and the intrinsic suitabilities, were made public so that developers could know where they planned to tread and, more positively, could be led to areas intrinsically suitable for their energies. Perhaps one of the most valuable innovations of the method is the conception of complementary land uses, the search for areas that can support more than one use. This tends to be in conflict with the principle of zoning, which enforces segregation of land uses. The recognition that certain areas are intrinsically suitable for several land uses can be seen either as a conflict or as the opportunity to combine uses in a way that is socially desirable. In many of the older European cities that are so extravagantly admired, there is a perfectly acceptable combination of residence and shopping and even certain manufacturing. It is possible to combine land uses but this requires some discretion and even art.

Normally land use maps, and even planning proposals, show broad categories of uses. The maps in this study are more like mosaics than posters—for good reason. They result from asking the land to display discrete attributes which, when superimposed, reveal great complexity. But this is the real complexity of opportunity and constraint. Yet it may appear anarchic, but only because we have become accustomed to the dreary consistency of zoning, because we are unused to perceiving the real variabilities in the environment, and responding to this in our plans.

Certain technical problems are inherent in the method. The first of these is the ensurance of parity of factors. The results will be qualified if the factors are of disproportionate weights. Too, there are limits to the photographic resolution of many factors and this study reached that threshold. The mechanical problem of transforming tones of gray into color of equal value is a difficult one, as is their combination. It may be that the computer will resolve this problem although the state of the art is not yet at this level of competence.

Such is the Staten Island Study. It is one of the most elaborate that the author has undertaken, it has moved forward some distance from the earlier studies, it does offer some hope for a planning process that is rational, explicit, replicatable and can employ the values of the community in its development.

The study of Staten Island was commissioned by The New York Department of Parks and produced by Wallace, McHarg, Roberts and Todd, under the direction of the author and performed by Mr. Narendra Juneja assisted by Messers. Meyers, Sutphin, Drummond, Ragan, Bhan and Mrs. Curry.

The ecological field studies were done by Dr. Archibald Reid and Mr. Charles Meyers. Soils maps were prepared by Dr. Howard M. Higbee.